CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 72 APRIL 1986 NUMBER 2

California Fish and Game is a journal devoted to the conservation and understanding of fish and wildlife. If its contents are reproduced elsewhere, the authors and the California Department of Fish and Game would appreciate being acknowledged.

Subscriptions may be obtained at the rate of $10 per year by placing an order with the California Department of Fish and Game, 1416 Ninth Street, Sacramento, CA 95814. Money orders and checks should be made out to California Department of Fish and Game. Inquiries regarding paid subscriptions should be directed to the Editor.

Complimentary subscriptions are granted on an exchange basis.

Please direct correspondence to:

Perry L. Herrgesell, Ph.D., Editor
California Fish and Game
1416 Ninth Street
Sacramento, CA 95814

CALIFORNIA FISH AND GAME

VOLUME 72 APRIL 1986 NUMBER 2

Published Quarterly by

STATE OF CALIFORNIA

THE RESOURCES AGENCY

DEPARTMENT OF FISH AND GAME

—LDA—

CONTENTS

Calif. Fish and Game 72(2): 68–77 1986

EPIDERMAL TUMORS IN *MICROSTOMUS PACIFICUS* (PLEURONECTIDAE) COLLECTED NEAR A MUNICIPAL WASTEWATER OUTFALL IN THE COASTAL WATERS OFF LOS ANGELES (1971–1983) [1]

JEFFREY N. CROSS
Southern California Coastal Water Research Project
646 W. Pacific Coast Highway
Long Beach, California 90806

The long-term temporal and geographic trends in the incidence of epidermal tumors in the *Microstomus pacificus* population on the mainland shelf off the Palos Verdes Peninsula are described. From 1971 through 1983, 501 *M. pacificus* (1.2% of total) with epidermal tumors were collected in 672 otter trawls. Tumors were generally confined to smaller individuals; 2.5% of the fish smaller than 150 mm SL were affected compared to 0.1% of the fish larger than 150 mm SL.

The annual incidence of tumors in *M. pacificus* declined at one of the four sampling sites and remained unchanged at the other three. Geographically, the incidence of tumors was higher closer to the wastewater outfalls. The data suggested that tumorous *M. pacificus* do not participate in the annual offshore migration to the same extent as unaffected individuals.

INTRODUCTION

Fin erosion and epidermal tumors are the most visible and prevalent external abnormalities observed in fish collected near the municipal wastewater outfalls in the coastal waters off Los Angeles (Mearns and Sherwood 1974, 1977; Sherwood and Mearns 1977). The status of fin erosion was reviewed recently (Cross 1985). The status of epidermal tumors has not been reviewed since the mid-1970's. Also known as X-cell tumors (Brooks, McArn, and Wellings 1969), they occur on the epidermis of some Bothidae, Pleuronectidae, and Gobiidae in the North Pacific Ocean (Cooper and Keller 1969; McArn and Wellings 1971; Miller and Wellings 1971; Mearns and Sherwood 1974; Ito, Kimura, and Miyake 1976; Oishi, Yamazaki, and Harada 1976; Wellings, McCain, and Miller 1976; McCain, Myers, and Gronlund 1978; Campana 1983) and on the parabranchial gland of some Gadidae and Scorpaenidae in the North Atlantic and North Pacific oceans (Dawe, Bagshaw, and Poore 1979; McCain et al. 1979; Myers 1981; Watermann and Dethlefsen 1982).

The objective of this study was to determine the long-term temporal (annual and seasonal) and geographic trends in the incidence of epidermal tumors in the *Microstomus pacificus* population in the coastal waters off Los Angeles from 1971 through 1983.

METHODS

The data analyzed in this study were collected by the Los Angeles County Sanitation District during regular monitoring cruises. The station numbers used herein are their designations. The data consisted of catch records of fishes and the frequency of tumors along seven transects on the Palos Verdes shelf (Figure 1). Trawls were made during daylight hours at three depths (23, 61, and 137 m)

[1] Accepted for publication November 1985. Contribution number 199 from Southern California Coastal Water Research Project.

with an otter trawl towed along a depth isobath at 1.1 m/s for 10 min. A 7.3-m (headrope length) otter trawl was used from 1971 to 1974 when it was replaced with a 7.6-m trawl; a 1.25-cm mesh cod-end liner was used in both nets. Fishes were sorted from the catch by species and measured to the nearest mm standard length (SL) on a measuring board if there were few individuals or to the nearest cm SL if there were many individuals. The presence of epidermal tumors was noted.

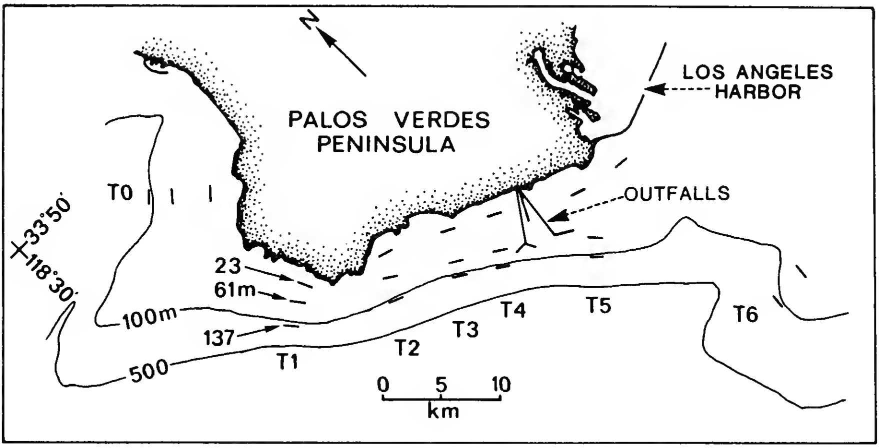

FIGURE 1. Map of the transect stations on the Palos Verdes shelf.

From 1971 through 1978, two samples were collected annually at each depth —one between April and June, the other between October and December. Additional trawls made at irregular intervals were included in the analyses. Quarterly trawling began in 1979 and has continued to the present. Trawling was discontinued at transects T2, T3, and T6 in 1977.

Trends in the annual incidence of epidermal tumors from 1971 through 1983 were determined by linear regression of the proportion of fish with tumors against time for each transect. All trawls made within a calendar year at transects T0, T1, T4, and T5 were pooled for each transect because of the low frequency of tumors in the *M. pacificus* population. Proportions (p) were transformed to the arcsin ($p^{1/2}$) to make the data conform more closely to the assumptions of regression analysis (Finney 1973). Annual tumor frequencies of zero were replaced by ¼n (Bartlett 1937). Time was coded as year of collection numbered consecutively from 1971 through 1983 (e.g., 1,2,3, . . ., 13). Trend analyses were performed on data for individuals less than 120 mm SL which accounted for 79.8% of all tumorous *M. pacificus* (382) collected at transects T0, T1, T4, and T5. According to the growth curves in Sherwood (1980), fish 120 mm SL were approximately two years old and probably had spent two summers on the mainland shelf. Visual analysis and runs tests of the residuals suggested linear relationships.

The quarterly trawls (1979–1983) from 61 and 137 m were examined for seasonal trends in the incidence of tumors and the total catch of *M. pacificus.* Transects T0, T1, T4, and T5 were combined for each quarter because of the low

frequency of tumors. Seasonal trends were estimated from:

$$Y_t = f(T_t, S_t) + e_t$$

where Y_t = the proportion with tumors at t, T_t = the trend component at time t, S_t = the seasonal component at time t, e_t = the remaining components (cyclical and aperiodic) at time t, and f is a function relating the observed value of the time series to the trend, seasonal, and remaining components (Bowerman and O'Connell 1979). Regressions were fitted to the incidence data to estimate T (the regression coefficient) for each quarter. The trend was eliminated by dividing the quarterly Y values by T. S was then estimated for each quarter (assuming e was small), normalized to four (the number of quarters in one year), and multiplied by 100. The seasonal index (S_t) is a correction factor (in percent) that adjusts for seasonality in the time series. Multiplicative and additive models were fitted to the data; multiplicative models gave a better fit (i.e., lower normalized residual sum of squares).

Between 1971 and 1972, a sample of 100 tumorous *M. pacificus* collected by trawls by various agencies from the Palos Verdes shelf, Santa Monica Bay, and San Pedro Bay were preserved aboard ship and returned to the laboratory for examination. The fish were measured to the nearest mm SL and the location, number, and size of the tumors on each fish were recorded.

RESULTS

From 1971 through 1983, 501 tumorous *M. pacificus* (1.2% of all individuals) were collected in 672 otter trawls on the Palos Verdes shelf. Tumors in *M. pacificus* were confined primarily to smaller individuals; 2.5% of the fish smaller than 150 mm SL were affected compared to 0.1% of the fish larger than 150 mm SL (Figure 2). Tumors were first observed in fish 50–59 mm SL and most frequently encountered in fish 100–109 mm SL; of all tumorous fish, only 0.1% were larger than 150 mm SL. The proportion of *M. pacificus* with tumors increased rapidly with fish size, peaking in fish 80–89 mm SL, and declined rapidly thereafter (Figure 3).

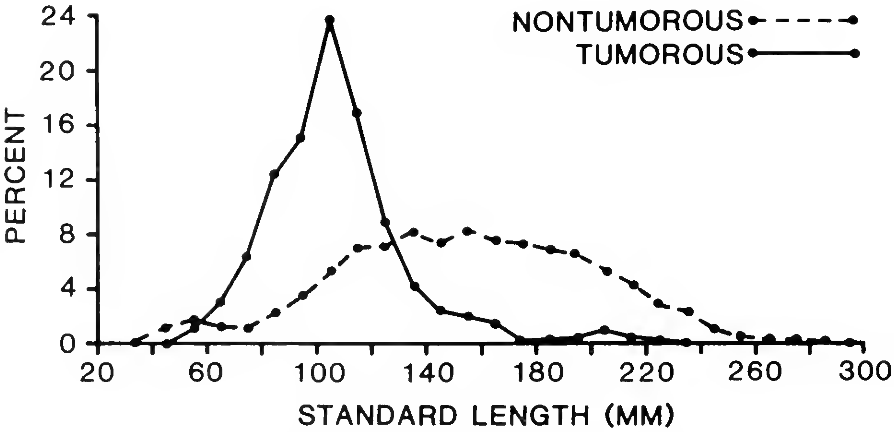

FIGURE 2. Size distribution of tumorous and nontumorous *Microstomus pacificus* collected on the Palos Verdes shelf from 1971 through 1983.

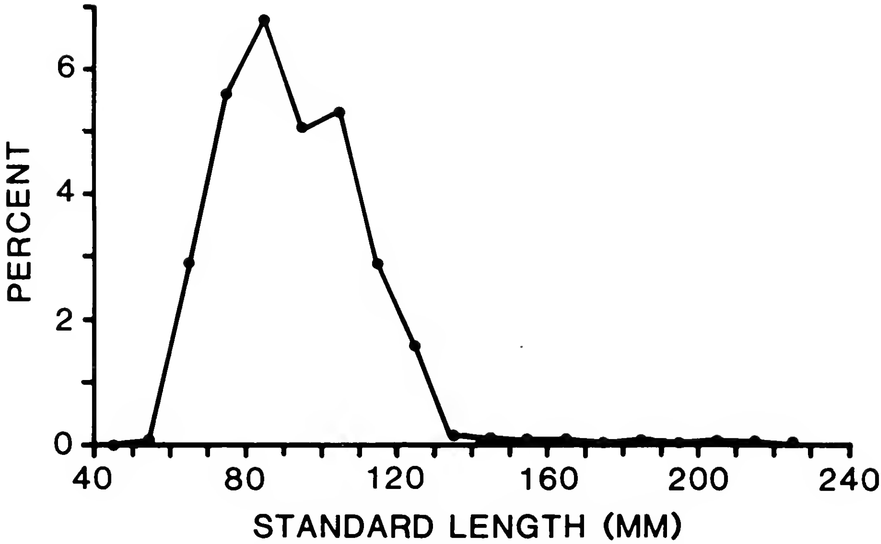

FIGURE 3. Percent of all *Microstomus pacificus* collected on the Palos Verdes shelf from 1971 through 1983 with epidermal tumors by 10 mm size class.

Among the sample of 100 tumorous *M. pacificus* collected in 1971 and 1972, there was no correlation between the number of tumors per fish and fish size ($r = -.131$, $.10 < P < .20$) (Figure 4). The fish ranged from 61 to 208 mm SL with a mode between 100 and 120 mm; 3.0% were larger than 150 mm. There was a significant correlation between tumor size and fish size ($r = .643$, $P < .001$) (Figure 5). Of the individuals with only one tumor ($n = 46$), 54.3% had it on the eyed side, 37.9% had it on the blind side, and 8.7% had it extend onto both sides. Of the individuals with more than one tumor ($n = 54$), 50.0% had tumors on both sides, 25.9% had tumors only on the eyed side, 13.0% had tumors only on the blind side, and 11.1% had at least one tumor extending onto both sides. Disregarding individuals with tumors on both sides, the ratio of fish with tumors on the eyed side to fish with tumors on the blind side was not significantly different from 1:1 ($\chi^2 = 3.57$, $n = 63$, $.05 < P < .10$).

There were no significant changes in the annual proportion of *M. pacificus* with tumors from 1971 through 1983 at transects T0, T4, and T5 (Tables 1 and 2). There was a significant decline in tumor incidence at transect T1. Analysis of covariance revealed no significant differences among the slopes of the regressions ($F = 1.26$, $P > .25$). There were significant differences among the intercepts ($F = 12.79$, $P < .001$) however, a Newman-Keuls multiple range test could not detect which transects were significantly different. The prevalence of tumorous individuals was significantly higher ($\chi^2 = 25.4$, $P < .001$) at transects closer to the outfall (T1, T4, and T5) than at the transect farthest away (T0) (Figure 6).

Time series analyses of the quarterly trawl data (1979–83) showed seasonal differences in both the proportion of *M. pacificus* with tumors and the number of *M. pacificus* caught per trawl (Figure 7). Interestingly, the trends were opposite: total catch was highest in spring and summer, while tumor incidence was highest in fall and winter.

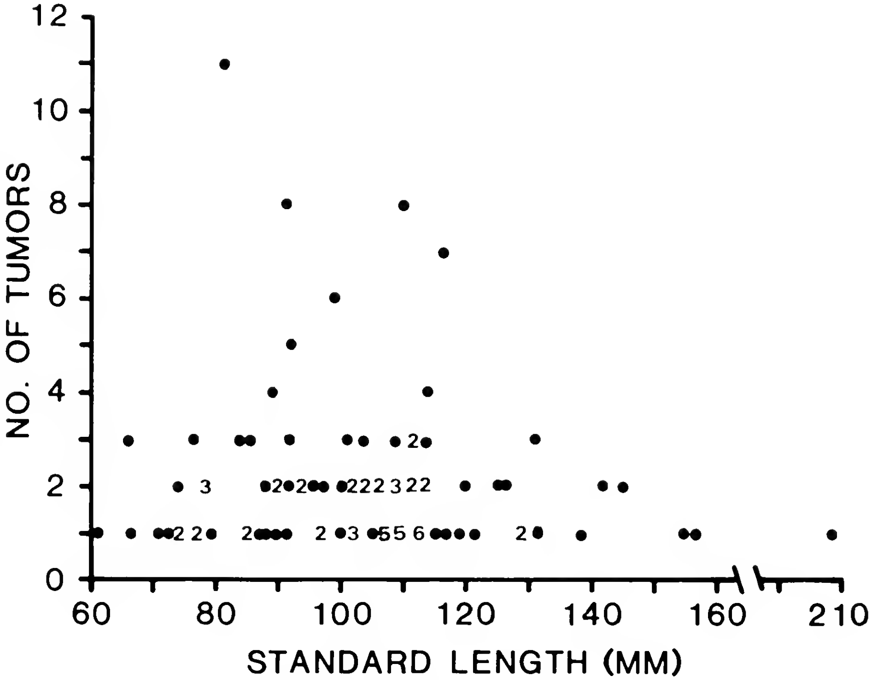

FIGURE 4. Number of epidermal tumors per *Microstomus pacificus* as a function of fish standard length. Numbers indicate multiple individuals.

TABLE 1. The Number of *Microstomus pacificus* Less Than 120m (SL) Collected and the Percent With Epidermal Tumors at Four Transects (T0, T1, T4, and T5) on the Palos Verdes Shelf From 1971 Through 1983.

	T0		*T1*		*T4*		*T5*	
	No.	*%*	*No.*	*%*	*No.*	*%*	*No.*	*%*
1971	26	0	26	15.4	17	11.8	91	7.7
1972	522	0.4	55	10.9	115	10.4	52	1.9
1973	82	3.7	15	12.5	268	9.0	57	14.0
1974	9	0	34	0	37	2.7	73	1.4
1975	7	0	3	0	22	22.7	36	2.8
1976	3	0	108	4.6	163	6.1	137	6.6
1977	26	0	135	3.7	840	3.2	311	5.5
1978	6	0	84	1.2	213	0.9	189	2.6
1979	48	4.2	69	5.8	398	4.0	357	3.1
1980	77	3.9	66	3.0	378	2.6	705	1.0
1981	82	3.7	103	5.8	530	1.3	237	3.0
1982	125	0	22	0	332	8.7	403	4.0
1983	251	0.8	93	1.1	96	6.3	269	4.8
Total	1264	1.2	814	4.4	3409	4.4	2917	3.5

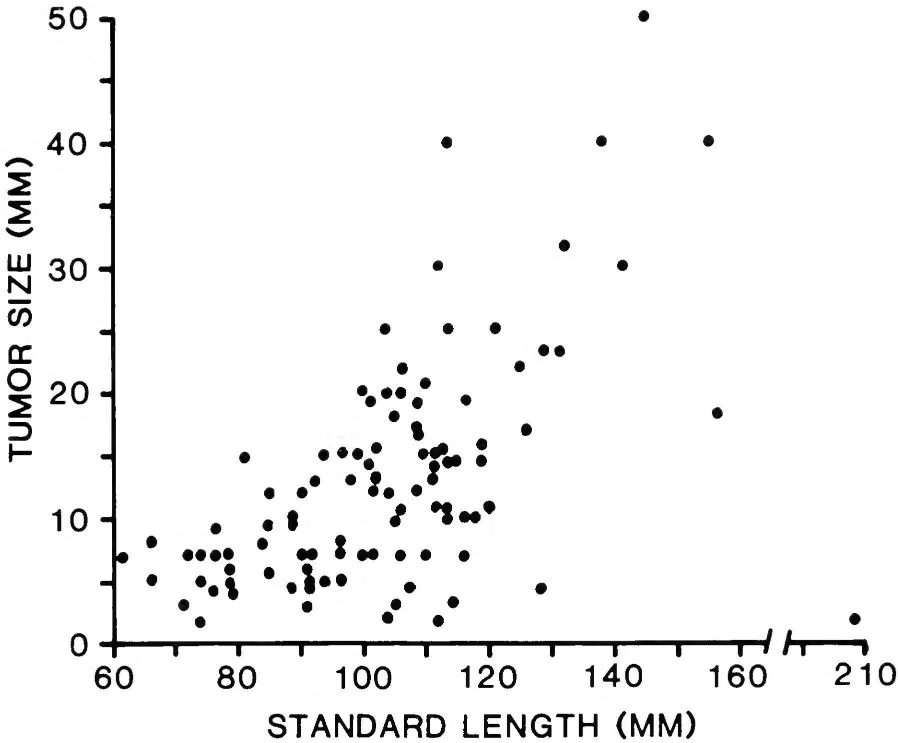

FIGURE 5. Tumor size (largest dimension) as a function of *Microstomus pacificus* standard length. Only the largest tumor was measured on individuals with multiple tumors.

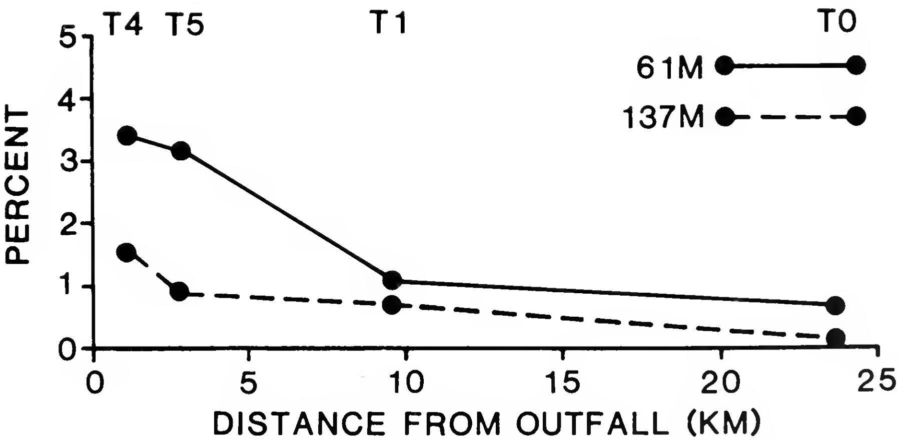

FIGURE 6. Percent of all *Microstomus pacificus* less than 120 mm SL with epidermal tumors as a function of distance from the municipal wastewater outfalls on the Palos Verdes shelf. The sampling transects are labeled at the top.

TABLE 2. Trend Analyses for *Microstomus pacificus* Less Than 120 mm SL Collected at Four Transects on the Palos Verdes Shelf (1971–1983). Y = Arcsin ($p^{1/2}$) Where p = Proportion With Epidermal Tumors; X = Time in Years Numbered Consecutively from 1971 (e.g., 1,2,3, . . ., 13); CI = 95% Confidence Interval of the Slope; *P* = Probability That the Slope = 0.

	Regression	*CI*	*P*
T0	Y = 9.233 – 0.033X	–0.733 to 0.667	*P*> 0.50
T1	Y = 18.930 – 1.022X	–1.913 to –0.091	*P*< 0.05
T4	Y = 19.048 – 0.706X	–1.680 to 0.268	*P*> 0.10
T5	Y = 13.801 – 0.321X	–1.034 to 0.392	*P*> 0.50

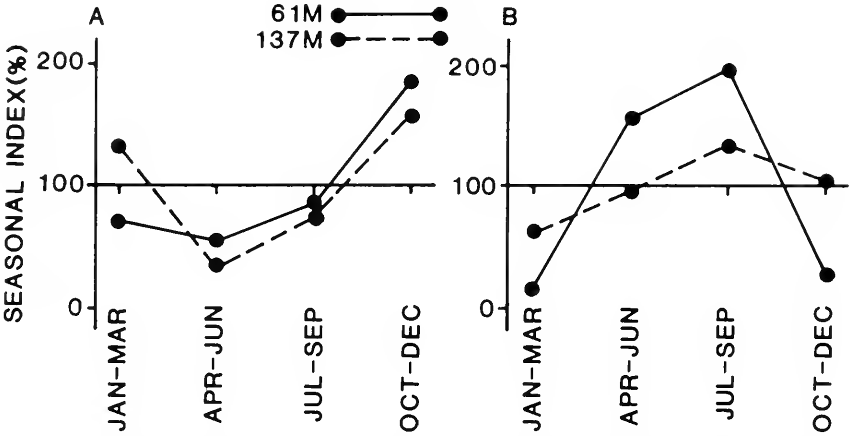

FIGURE 7. Seasonal index for (A) the proportion of *Microstomus pacificus* with epidermal tumors and (B) the total catch of *M. pacificus* per trawl from 1979 through 1983.

DISCUSSION

The incidence of epidermal tumors in *M. pacificus* was highest in fish less than two years old. Based on an age-length key for *M. pacificus* collected in 1972 and 1973 (Cross 1985), only 6.2% of the tumorous individuals collected between 1971 and 1983 were age two or older. Epidermal tumors of presumed similar etiology were restricted to the youngest individuals in several other species of Pleuronectidae from the West Coast (Cooper and Keller 1969, McArn and Wellings 1971, Wellings et al. 1976, Campana 1983).

Tumors were not observed on the smallest *M. pacificus* recruits (40–49 mm SL) in the first quarter (January–March), but appeared in larger fish (50–59 mm SL) in the second quarter (April–June). Similarly, Campana (1983) found that *Platichthys stellatus* (Pleuronectidae) in Puget Sound settled from the plankton as early as May but the first tumors did not appear until July.

There was no correlation between fish size and number of tumors per fish and fish with tumors on the eyed side were not significantly more abundant than fish with tumors on the blind side. Wellings et al. (1976) reported that tumors were more abundant on the eyed side in *Parophrys vetulus* and *Hippoglossoides elassodon* (Pleuronectidae).

There was a correlation between fish size and tumor size: larger fish had larger tumors (Sherwood and Mearns 1976). Campana (1983) found that tumors on

P. stellatus continued to grow as the fish grew; there was no evidence for tumor regression. Similarly, Miller and Wellings (1971) found no evidence of tumor regression in *H. elassodon* from northern Puget Sound.

The rapid decline in the proportion of tumorous *M. pacificus* with increasing fish size suggests that either i) tumorous fish have higher mortality rates than nontumorous fish or ii) tumorous fish have higher emigration rates from the study area. The former hypothesis is supported by data of Campana (1983), who found that tumorous *P. stellatus* were more susceptible to stress, had lower growth rates, and had much higher mortality rates than nontumorous individuals, and by the data of Miller and Wellings (1971), who found that tumorous *H. elassodon* had lower growth rates and higher mortality rates than nontumorous individuals.

The proportion of *M. pacificus* with tumors was highest in the fall and winter when the total catch was lowest. The seasonal pattern of total catch is the result of an annual onshore-offshore migration. *M. pacificus* move into shallow water to feed in the spring and summer and move back into deeper water in the fall and winter (Hagerman 1952). Seasonality was more pronounced at the shallower depth. The higher proportion of tumorous fish on the Palos Verdes shelf in the fall and winter suggests that tumorous individuals do not participate in the offshore movement to the same extent as do nontumorous individuals. Stich, Acton, and Forrester (1976) suggested that the emigration of juvenile *Parophrys vetulus* from shallow nursery areas to deeper water off British Columbia may be slower in individuals with epidermal tumors.

The annual incidence of tumors in *M. pacificus* did not change at transects T0, T4, and T5 from 1971 through 1983 but declined significantly at T1. The incidence of fin erosion in the *M. pacificus* population declined significantly at all transects during this period (Cross 1985). Declines in the incidence of fin erosion were correlated with declines in the mass emission of contaminants from the outfalls and declines in the body burden of contaminants among *M. pacificus*. The decline in tumor incidence at T1 suggests that tumors were somehow affected by reduced contamination in the environment.

There was a significant geographical difference in the incidence of tumors in *M. pacificus* less than 120 mm SL: 1.2% of all individuals collected at T0 had tumors while 4.4% of the individuals at T1, 4.4% of the individuals at T4, and 3.5% of the individuals at T5 had tumors. The incidence of epidermal tumors in the *M. pacificus* population apparently is enhanced near the outfalls (Figure 6). Similarly, the incidence of fin erosion in the *M. pacificus* population is enhanced near the outfalls (Cross 1985). Among all *M. pacificus* less than 120 mm SL collected from 1971 through 1983, 16.9% had fin erosion, 3.2% had epidermal tumors, and 1.1% had both diseases. The two diseases were not independent; significantly more individuals were afflicted with both diseases than predicted ($X^2 = 45.4$, $P < .001$).

Cooper and Keller (1969) and Stich et al. (1976) found elevated epidermal tumor incidence in *P. vetulus* in urban estuaries and Sindermann (1983) tentatively associated X-cell tumors with environmental degradation. Mearns and Sherwood (1976), however, concluded that the incidence of epidermal tumors in *M. pacificus* populations in southern California was not enhanced by municipal wastewater discharge. They cited as evidence the occurrence of tumorous individuals in areas far from municipal wastewater discharges (see also Sherwood and Mearns 1976). The occurrence of epidermal tumors in pleuronectids far from degraded environments may be related to the etiology of the disease.

Recent evidence suggests that the X-cell is a unicellular protozoan parasite resembling parasitic amoebae (Dawe et al. 1979, Dawe 1981, Myers 1981, Watermann and Dethlefsen 1982) although not everyone agrees with this interpretation (Peters, Stich, and Kranz 1981, Peters et al. 1983). Newly recruited pleuronectids may be susceptible to epidermal tumors because of contaminant-induced stress and/or an incompletely developed immune system (Sindermann 1983).

ACKNOWLEDGMENTS

I would like to thank Los Angeles County Sanitation District for access to the monitoring data, A. J. Mearns and M. J. Sherwood for access to the tumor data on Dover sole collected in 1971 and 1972, and M. Martin for helpful comments on an earlier version of the manuscript.

LITERATURE CITED

Bartlett, M.S. 1937. Some examples of statistical methods of research in agriculture and applied biology. Royal Stat. Soc., J. Suppl., 4:137–170.

Bowerman, B.L., and R. T. O'Connell. 1979. Time series and forecasting: an applied approach. Duxbury Press, North Scituate, Mass., 481 p.

Brooks, R.E., G.E. McArn, and S.R. Wellings. 1969. Ultrastructural observations on an unidentified cell type found in epidermal tumors of flounders. Natl. Cancer Inst., J., 43:97–100.

Campana, S.E. 1983. Mortality of starry flounders *(Platichthys stellatus)* with skin tumors. Can. J. Fish. Aquat. Sci., 40:200–207.

Cooper, R.C., and C.A. Keller. 1969. Epizootiology of papillomas in English sole, *Parophyrs vetulus.* Natl. Cancer Inst. Monog., 31:173–185.

Cross, J.N. 1985. Fin erosion among fishes collected near a southern California municipal wastewater outfall (1971–1982). Fish. Bull., 83:195–206.

Dawe, C.J., J. Bagshaw, and C.M. Poore. 1979. Amoebic pseudotumors in pseudobranchs of Pacific cod, *Gadus macrocephalus.* Amer. Assoc. Cancer Res., Proc., 20:245.

Dawe, C.J. 1981. Polyoma tumors in mice and X-cell tumors in fish, viewed through telescope and microscope. Pages 19–49 *in* C.J. Dawe, J.C. Harshbarger, S. Kondo, T. Sugimura, and S. Takayama eds. Phyletic approaches to cancer. Japan Sci. Soc. Press, Tokyo.

Finney, D.J. 1973. Transformation of observations for statistical analysis. Cotton Grow. Rev., 50:1–14.

Hagerman, F.B. 1952. The biology of Dover sole, *Microstomus pacificus* (Lockington). Calif. Dept. Fish and Game, Bull. (85) 48 p.

Ito, Y., I. Kimura, and T. Miyake. 1976. Histopathological and virological investigations of papillomas in soles and gobies in coastal waters of Japan. Prog. Exp. Tumor Res., 20:86–93.

McArn, G.E., and S.R. Wellings. 1971. A comparison of skin tumors in three species of flounders. Fish. Res. Bd. Can., J., 28:1241–1251.

McCain, B.B., M.S. Myers, and W.D. Gronlund. 1978. The frequency distribution and pathology of three diseases of demersal fishes in the Bering Sea. J. Fish Biol., 12:267–276.

McCain, B.B., W.D. Gronlund, M.S. Myers, and S.R. Wellings. 1979. Tumors and microbial diseases of marine fishes in Alaska waters. J. Fish. Dis., 2:111–130.

Mearns, A.J., and M. Sherwood. 1974. Ecological aspects of two diseases of the Dover sole *(Microstomus pacificus)* from southern California coastal waters. Am. Fish. Soc., Trans., 103:799–810.

———1976. Ocean wastewater discharge and tumors in a southern California flatfish. Prog. Exp. Tumor Res., 20:75–85.

———1977. Distribution of neoplasms and other diseases in marine fishes relative to the discharge of wastewater. N.Y. Acad. Sci., Ann., 298:210–224.

Miller, B.S., and S.R. Wellings. 1971. Epizootiology of tumors on flathead sole *(Hippoglossoides elassodon)* in East Sound, Orcas Island, Washington. Am. Fish. Soc., Trans., 100:247–266.

Myers, M.S. 1981. Pathologic anatomy of papilloma-like tumors in the Pacific Ocean perch, *Sebastes alutus,* from the Gulf of Alaska. Thesis, Univ. Washington, Seattle. 98 p.

Oishi, K., F. Yamazaki, and T. Harada. 1976. Epidermal papillomas of flatfish in the coastal waters of Hokkaido, Japan. Fish. Res. Bd. Can., J., 33:2011–2017.

Peters, N., H. Stich, and H. Kranz. 1981. The relationship between lymphocystis disease and X-cell papillomatosis in flatfish. Pages 111–121 *in* C.J. Dawe, J.C. Harshbarger, S. Kondo, T. Sugimura, and S. Takayama eds. Phyletic

approaches to cancer. Japan Sci. Soc. Press, Tokyo.

Peters, N., W. Schmidt, H. Kranz, and H.F. Stich. 1983. Nuclear inclusions in the X-cells of skin papillomas of Pacific flatfish. J. Fish Dis., 6:533–536.

Sherwood, M. 1980. Recruitment of nearshore demersal fishes. Pages 319–333 *in* W. Bascom ed. Coastal Water Research Project Biennial Report 1979–1980. Southern California Coastal Water Research Project, Long Beach.

Sherwood, M.J., and A.J. Mearns. 1976. Occurrence of tumor-bearing Dover sole *(Microstomus pacificus)* off Point Arguello, California, and off Baja California, Mexico. Am. Fish. Soc., Trans., 105:561–563.

________. 1977. Environmental significance of fin erosion in southern California demersal fishes. N.Y. Acad. Sci., Ann., 298:177–189.

Sindermann, C.J. 1983. An examination of some relationships between pollution and disease. Rapp. P.-v. Reun. Cons. int. Explor. Mer, 182:37–43.

Stich, H.F., A.B. Acton, and C.R. Forrester. 1976. Fish tumors and sublethal effects of pollution. Fish. Res. Bd. Can., J., 33:1993–2001.

Watermann, B., and V. Dethlefsen. 1982. Histology of pseudobranchial tumors in Atlantic cod *(Gadus morhua)* from the North Sea and the Baltic Sea. Helgolander Wiss. Meeresunters, 35:231–242.

Wellings, S.R., B.B. McCain, and B.S. Miller. 1976. Epidermal papillomas in Pleuronectidae of Puget Sound, Washington. Prog. Exp. Tumor Res., 20:55–74.

Calif. Fish and Game 72(2): 78–82 1986

THE OCCURRENCE OF TWO NEMATODES, *SPIROCERCA LUPI* AND *DIROFILARIA IMMITIS*, IN WILD CANIDS OF THE LAKE BERRYESSA AREA, NORTHERN CALIFORNIA [1]

M. M. J. LAVOIPIERRE [2], T. W. GRAHAM [3], L. L. WALTERS [4], and J. A. HOWARTH
Department of Epidemiology and Preventive Medicine
School of Veterinary Medicine
University of California
Davis, California 95616

Spirocerca lupi was found in 4 of 17 (24%) gray foxes, *Urocyon cinereoargenteus*, trapped at Lake Berryessa, northern California. The nematodes, dissected from granulomas, were located in the upper colon and ileo-colic portion of the gut. Five adult *Dirofilaria immitis* were found in the heart of one of the foxes. *D. immitis* was found also in the hearts of three of four coyotes, *Canis latrans*, taken in the same area (23, 36 and 94 adult nematodes).

INTRODUCTION

During a study of the ecology of carnivore tapeworms in northern California, including the City of Davis and surrounding area, a number of wild canids were captured for necropsy. Foxes taken from a foothill locality west of Davis were found to harbor the nematode, *Spirocerca lupi*; coyotes and foxes from this site harbored the filaroid nematode, *Dirofilaria immitis*.

Discovery of *S. lupi* in foxes is of particular interest because this parasite has been rarely documented in this host (Buechner 1944, Bailey 1963), and autochthonous cases of spirocercosis have not been previously reported from California. *D. immitis*, however, is highly endemic in some dog (Walters and Lavoipierre 1984) and coyote (Weinmann and Garcia 1980, Acevedo and Theis 1982) populations of northern California. Recovery of *D. immitis* fom coyotes in this foothill locality may be epidemiologically relevant in light of documentation of autochthonous *D. immitis* in domestic dogs of an adjacent community (Walters et al. 1981); coyotes have been considered potential reservoirs of the parasite to dogs in other rural foci (Gier and Ameel 1959; Monson, Stone and Weber 1973; Crowell et al. 1978).

MATERIALS AND METHODS

All animals were captured in the Coast Range foothills near Lake Berryessa, northern California, either in Markley Canyon (Napa Co.) or in Pleasants Valley (Solano Co.). During February 1978–January 1979, 21 animals were necropsied and examined for helminth parasites. These included 17 gray foxes, *Urocyon cinereoargenteus*, and 4 coyotes, *Canis latrans*. Special attention was paid at necropsy to the presence of helminths in the alimentary canal, body cavities, vascular system, lungs, and kidneys. Nematodes were preserved in a 70% ethanol/glycerol mixture (95 parts/5 parts). Heart blood was examined for microfilariae of *D. immitis* by direct smear (coyotes) or by the Difil [R] method (foxes).

---

[1] Accepted for publication July 1985.
[2] Dr. Lavoipierre deceased 1 Nov. 1984. Send reprint requests to Dr. Walters.
[3] Current address: Ferndale Veterinary, P.O. Box 1032, Ferndale, CA 95536.
[4] Current address: Yale University School of Medicine, Dept. Epidemiology and Public Health, P.O. Box 3333, 60 College St., New Haven, CT 06510.

RESULTS

Four of the 17 (24%) foxes were found to be infected with *S. lupi* (Figure 1). In each of the four infected animals, male and female nematodes were found in granulomas at and posterior to the ileo-colic junction of the ileum and colon. No gross lesions were recognizable in the thoracic organs. In one case, the granulomas were so large that they appeared to be causing a stricture of the colon close to the ileo-colic junction.

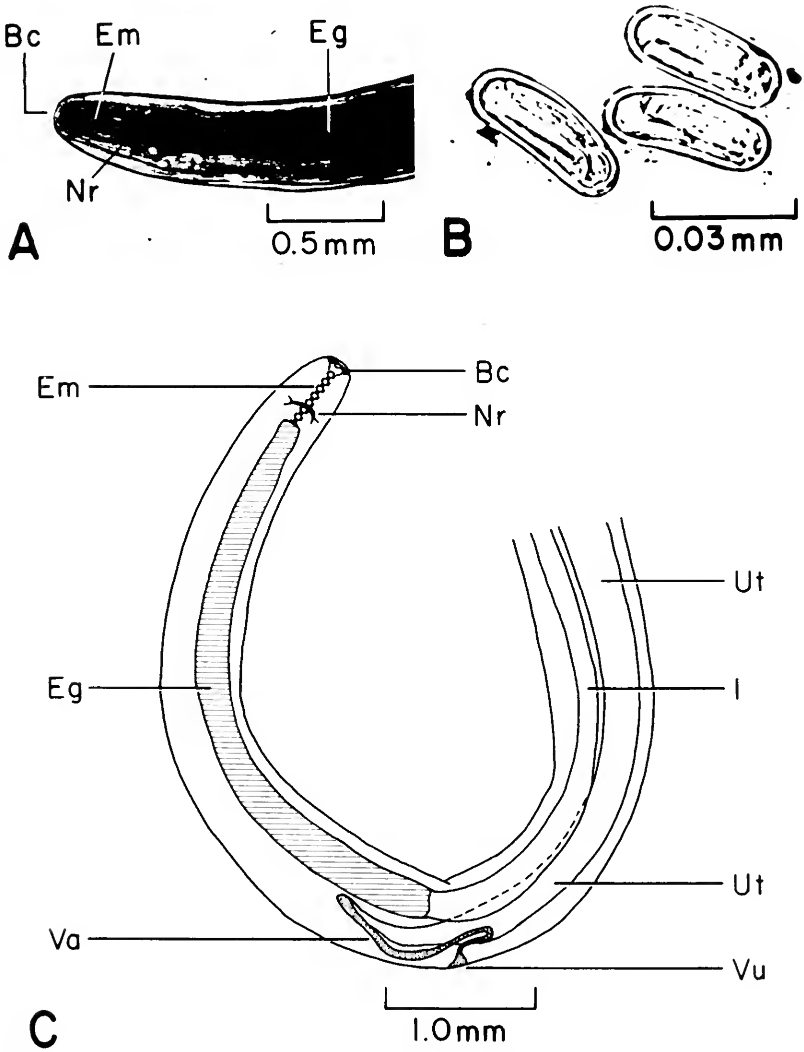

FIGURE 1: A. Anterior end of a female *Spirocerca lupi* dissected from a granuloma at the ileo-caecal junction of a gray fox. B. A photograph of three eggs of *Spirocerca lupi* dissected out of the uterus of a gravid female worm. C. A schematic view of the anterior end of a female *Spirocerca lupi* from a gray fox to show the position of the vulva relative to the esophagus. Note that the vulva opens far forwards on the body of the nematode. Bc, buccal capsule; I, intestine; Nr, nerve ring; Eg, esophagus-glandular portion; Em, esophagus-muscular portion; Ut, uterus; Va, vagina; Vu, vulva.

D. immitis was found in only one of the foxes. Five adult worms (3 females, 2 males) were located in the right ventricle of the heart; circulating microfilariae were not detected. In three of the four coyotes examined, adult heartworms were recovered from the right ventricle. Infected animals harbored 94 (44 females, 50 males), 36 (22 females, 14 males), and 23 (9 females, 14 males) worms; circulating microfilariae were detected in the blood of each infected coyote.

DISCUSSION

Although the fox, in addition to other carnivores, is known to be a host to *S. lupi*, records of the occurrence, or the possible occurrence, of the worm in this host in the United States are limited to the reports of Buechner (1944), Bailey (1963), and Pence and Stone (1978).

In the dog (Bailey 1963, 1972) and the coyote (Smith 1971; Thornton, Bell and Reardon 1974; Pence and Stone 1978; Morrison and Gier 1979), *S. lupi* is found in the upper alimentary canal (the esophagus) and in the thoracic and abdominal aorta. In the foxes we examined, however, the nematodes were in the lower intestine. Likewise, in the only case of fox spirocercosis seen by Bailey (1963), "The parasites were embedded in nodules in the wall of the colon." Pence and Stone (1978) recorded aortic lesions resembling those caused by *S. lupi* in one gray and one red fox in an area in Texas where coyotes were infected by the nematode; no worms however, were recovered from the foxes.

Our discovery of a high proportion of foxes infected with *S. lupi* from a relatively delimited area in the Lake Berryessa hills indicates the presence of an autochthonous focus of spirocercosis in California. This is interesting since Bailey (1972) summarizing " . . . information on the prevalence of *Spirocerca lupi* in the United States, based on data from necropsy records of U.S. colleges of veterinary medicine", found that between 1952–1970 some 8,000 dogs were examined in California and only 3 were found to have spirocercosis. These cases were considered imported. Several of our clinical colleagues at the Veterinary Medical Teaching Hospital (VMTH) in Davis (Drs. I. M. Gourlay, D. R. Strombeck, P. F. Suter) who have had considerable experience with dogs assure us that they have no familiarity with the disease in this area. A computer search of the hospital records for the years 1967–79 (Dr. Suter pers comm.) found no incidence of *S. lupi* in the esophagus of dogs presented for treatment at the VMTH. Spirocercosis, therefore, appears to be non-existent, or very rare in dogs of northern California. We can only speculate as to the origin of the present spirocercosis focus in foxes near Lake Berryessa. The area is a popular vacation spot visited by many dog owners, not only from California but also from out-of-state, and it is possible that the parasite may have been introduced by a visiting dog from elsewhere in the United States. At the present time, in many areas of California, suitable conditions (Bailey 1972) exist for the natural cycling of *S. lupi*. If our experience with dirofilariasis in California (Walters and Lavoipierre 1982, 1984) is any indication of future trends in the epidemiological pattern of spirocercosis, then more cases may come to light.

The large numbers of *D. immitis* found in the heart of infected coyotes of the Berryessa area suggests multiple infections of these animals by local mosquito vectors. Particularly noteworthy was the coyote harboring 94 worms in the heart, this being the greatest number documented in the United States (Ameel 1955; Gier and Ameel 1959; Monson, Stone and Weber 1973; Graham 1975;

Franson, Jorgenson and Boggess 1976; Kazacos 1977; Crowell et al. 1978; Kazacos and Edberg 1979; Weinmann and Garcia 1980; Custer and Pence 1981). Whether the prevalence of microfilaremic coyotes in a specific geographic area reflects the prevalence of dirofilariasis in domestic dogs, at present, remains unanswered in California. Acevedo and Theis (1982) have suggested that in some areas of northern California a sylvatic cycle with urban spillover may be occurring; however, concurrent studies of dog and coyote populations in specific localities are generally lacking. In the Pleasants Valley area, the present study and Acevedo and Theis (1982) have both indicated a high prevalence of heartworm infection in coyotes. In domestic dogs of Pleasants Valley, a community-based survey during 1979 detected only 2/97 (2.1%) microfilaremic animals (Walters et al. 1981). Both cases, however, were considered autochthonous and probably unrelated (dogs resided 5.6 km apart), and therefore, may have resulted from mosquito transmission via a coyote reservoir, if wild and domestic cycles interdigitate. High prevalence of heartworm (21.1–34.3%) in dogs of other northern California communities (Walters and Lavoipierre 1984) suggests that the parasite may be maintained in a domestic dog cycle; however, the contribution of a coyote reservoir in these areas has not been explored.

ACKNOWLEDGMENTS

We are grateful to W. Sievers who trapped all the animals. S. Karr and P. Budwiser provided valuable assistance in several ways and we extend to them our thanks. Finally, we are indebted to the Office of the Dean, School of Veterinary Medicine, University of California, at Davis, for a grant, BRSG 79-10, which assisted us in defraying part of the expenses for this study.

LITERATURE CITED

Acevedo, R. A., and J. H. Theis. 1982. Prevalence of heartworm (*Dirofilaria immitis* Leidy) in coyotes from five northern California counties. Am. J. Trop. Med. Hyg., 31(5): 968–972.

Ameel, D. J. 1955. Parasites of the coyote *Canis latrans* Say, in Kansas. J. Parasitol., 41: 325.

Bailey, W. S. 1963. Parasites and cancer: sarcoma in dogs associated with *Spirocerca lupi*. Ann. N.Y. Acad. Sci., 108 (Art. 3): 890–923.

———. 1972. *Spirocerca lupi*: a continuing inquiry. J. Parasitol., 58: 3–22.

Buechner, H. K. 1944. Helminth parasites of the gray fox. J. Mammol., 25: 185–188.

Crowell, W. A., T. R. Klei, D. I. Hall, N. K. Smith, and J. D. Newsom. 1978. Occurrence of *Dirofilaria immitis* and associated pathology in coyotes and foxes from Louisiana. Pages 10–13 *in* H. C. Morgan, ed. Proceedings of the heartworm symposium —1977. VM Publishing Inc., Bonner Springs, Kansas.

Custer, J. W., and D. B. Pence. 1981. Dirofilariasis in wild canids from the gulf coastal prairies of Texas and Louisiana, U.S.A. Vet. Parasitol., 8: 71–82.

Franson, J. C., R. D. Jorgenson, and E. K. Boggess. 1976. Dirofilariasis in Iowa coyotes. J. Wildl. Dis., 12: 165–166.

Gier, H. T., and D. J. Ameel. 1959. Parasites and diseases of Kansas coyotes. Kans. Agric. Exp. Sta. Bull. 91. 34 p.

Graham, J. M. 1975. Filariasis in coyotes from Kansas and Colorado. J. Parasitol., 61: 513–516.

Kazacos, K. R. 1977. *Dirofilaria immitis* in wild Canidae from Indiana. Proc. Helminth. Soc. Wash., 44: 233–234.

Kazacos, K. R., and E. O. Edberg. 1979. *Dirofilaria immitis* infection in foxes and coyotes in Indiana. J. Am. Vet. Med. Assoc., 175 (9): 909–910.

Monson, R. A., W. B. Stone, and B. L. Weber. 1973. Heartworms in foxes and wild canids in New York. N.Y. Fish and Game J., 20(1): 48–53.

Morrison, E. E., and H. T. Gier. 1979. Parasitic infection of *Filaroides osleri, Capillaria aerophila* and *Spirocerca lupi* in coyotes (*Canis latrans*) from the southwestern USA. J. Wildl. Dis., 15: 557–560.

Pence, D. B., and J. E. Stone. 1978. Visceral lesions in wild carnivores naturally infected with *Spirocerca lupi*. Vet. Pathol., 15: 322–331.

Smith, J. P. 1971. Parasitic aortic aneurysms of coyotes. Pages 259–263 *in* S. M. Gaafar, ed. Pathology of parasitic diseases. Purdue Univ. Press, Lafayette, Indiana.

Thornton, J. E., R. R. Bell, and M. J. Reardon. 1974. Internal parasites of coyotes in southern Texas. J. Wildl. Dis., 10: 232–236.

Walters, L. L., and M. M. J. Lavoipierre. 1982. *Aedes vexans* and *Aedes sierrensis* (Diptera: Culicidae): potential vectors of *Dirofilaria immitis* in Tehama County, northern California, USA. J. Med. Entomol., 19(1): 15–23.

———. 1984. Landscape epidemiology of mosquito-borne canine heartworm (*Dirofilaria immitis*) in northern California, USA. I. Community-based surveys of domestic dogs in three landscapes. J. Med. Entomol., 21(1): 1–16.

Walters, L. L., M. M. J. Lavoipierre, K. I. Timm, and S. E. Jahn. 1981. Endemicity of *Dirofilaria immitis* and *Dipetalonema reconditum* in dogs of Pleasants Valley, northern California. Amer. J. Vet. Res., 42(1): 151–154.

Weinmann, C. J., and R. Garcia. 1980. Coyotes and canine heartworm in California. J. Wildl. Dis., 16: 217–221.

Calif. Fish and Game 72(2): 83–93 1986

GROWTH AND REPRODUCTION OF SPOT PRAWNS IN THE SANTA BARBARA CHANNEL [1]

JOHN S. SUNADA
Marine Resources Division
Department of Fish and Game
245 W. Broadway, Suite 350
Long Beach, California 90802

Growth and reproduction studies were conducted on spot prawn, *Pandalus platyceros,* taken from commercial landings in Santa Barbara during 1981 through 1983. Maximum age was estimated to be 6 years. Males became mature at age 3, averaging 40 mm CL, with the transitional stage averaging 45 mm CL and females near 48 mm CL at age 4. Nearly all females were in the ovigerous stage by December. Sex ratio for 1981–82 season was 2.46 males to one female, but was near a 1:1 ratio in the 1982–83 season.

INTRODUCTION

The spot prawn, *Pandalus platyceros,* a pandalid found from Alaska to San Diego, has been described in detail. Much is known about age and growth (Berkeley 1930, Butler 1964). More recent growth studies were conducted under laboratory conditions (Kelly, Haseltine, and Ebert 1977). The majority of these studies were based on data from specimens captured in British Columbia and Monterey. The Santa Barbara Channel population, located at the southern range, appears to display a longer longevity and later sexual transformation (Figure 1). This resource has become a significant fishery in this region, contributing nearly 118,200 kg in 1981, with an ex-vessel value of $524,000. Such a valuable resource requires proper management. Basic growth and age parameters are essential for deriving population estimates. This study was initiated to provide data in the development of a management scheme.

METHODS AND MATERIALS

Nearly all of the 4,536 individuals used in this study were measured and sexed at various fish markets located in Santa Barbara, Ventura, and Terminal Island (Figure 1). Measurements were taken to the nearest mm by means of a vernier caliper. Carapace length (CL) was determined by measuring from the base of the eyesocket to the posterior midline of the carapace. Age was determined by graphing length frequencies and separating modes by a method using probability paper as described by Harding (1949) and Cassie (1954).

Sexes were determined on location by examination of the second pleopod for absence or presence of the appendix masculina, a male characteristic. These prawns are protandric hermaphrodites, undergoing a sex change to females in later years. A total of 90 individuals was weighed and measured for determining a length-weight relationship. Weights were recorded to the nearest tenth of a gram.

Growth rates and parameters were determined by use of the Von Bertalanffy growth equation using the program BGC2 (Abramson 1971).

[1] Accepted for publication December 1985.

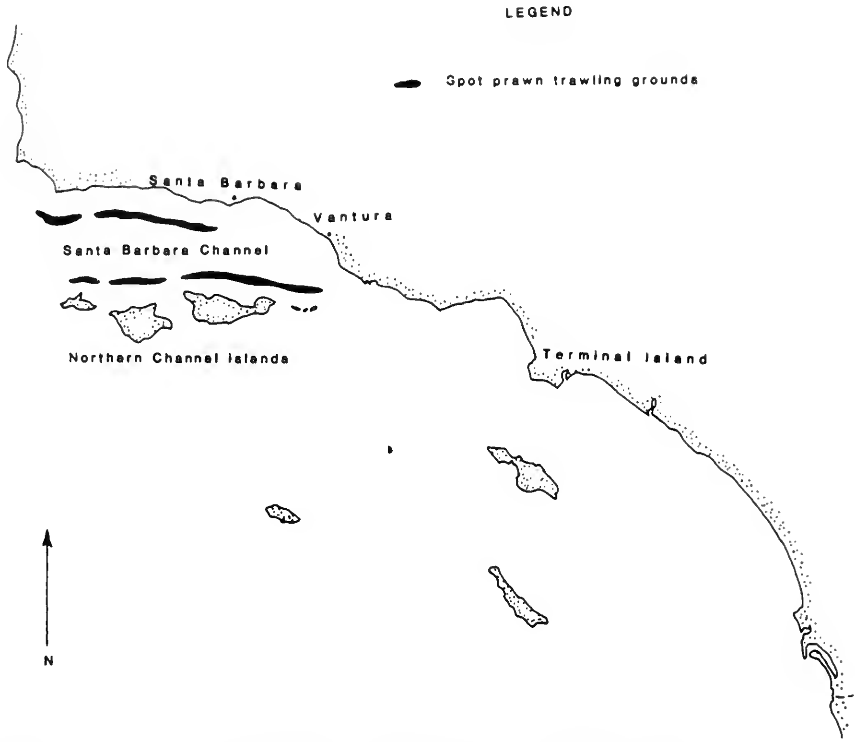

FIGURE 1. Location of fish markets and fishing grounds in southern California.

RESULTS

Growth

Designation of a Birthdate

Spot prawns are known to spawn in the fall and incubate their eggs until late winter. Since the majority of females have shed their eggs by April, and hatching has most likely occurred, 1 April was designated as the birthdate.

Modal Progression Analysis

Length frequencies taken during the April–May period of 1981 displayed several modes with a major peak near 40 mm carapace length (Figure 2). This mode was believed to represent the 1978 year class or age group 3. A second less pronounced mode occurred near 50 mm CL, representing the 1977 year class (age group 4) and a minor peak near 30 mm CL (the 1979 year class or age group 2).

Incremental increases in growth for age group 3 occurred slightly throughout the year and to a lesser degree, with age group 4. By the January–March period, numbers of age group 2 animals increased in the catch. These prawns measured 35 mm CL. The prawns taken during the April to May quarter increased in size to 37 mm CL by 1 April 1982, when they had completed their third year.

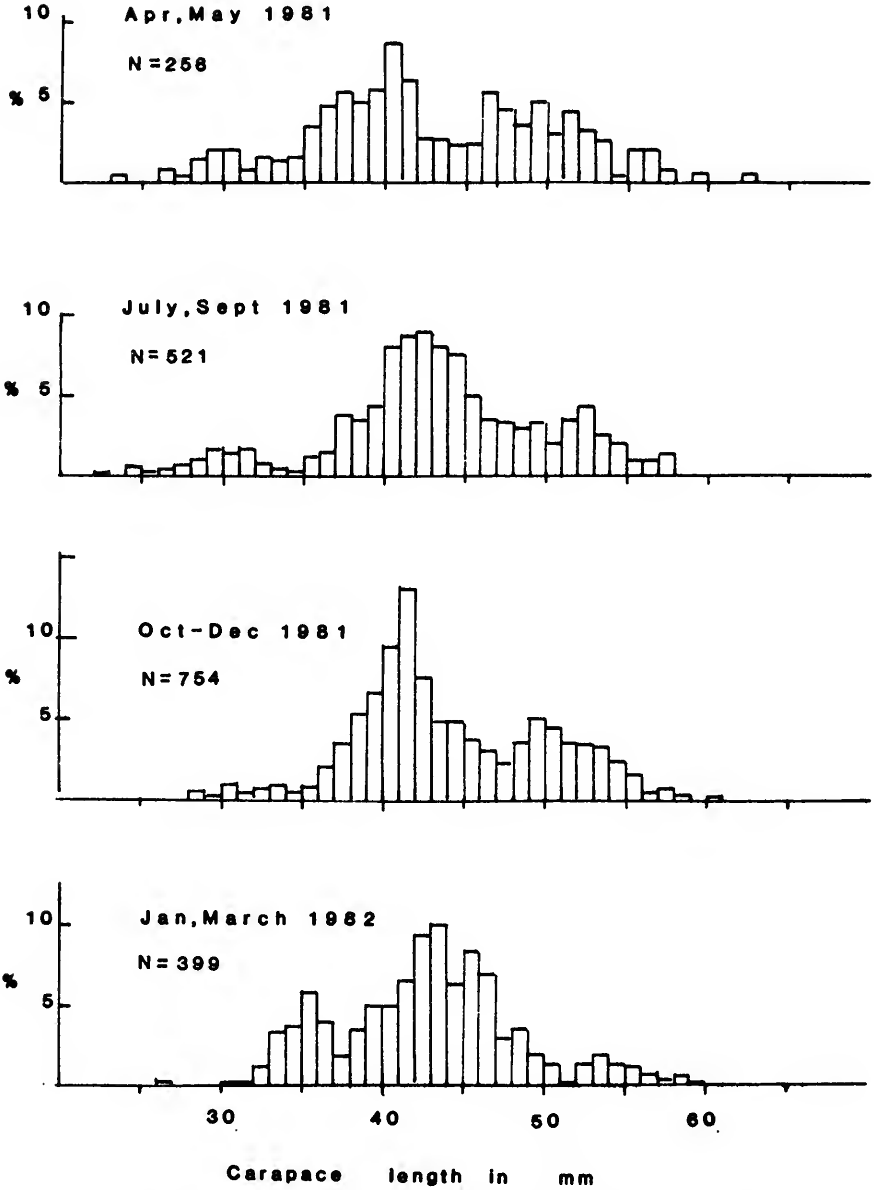

FIGURE 2a. Length frequency distribution of spot prawns during 1981 through 1983.

Beginning in the April–June period of 1982, the 1978 year class (now age group 4) continued to dominate the catch, in addition to the 1977 cohort (age group 5) (Figure 2). The 1978 year class continued to occur near 45 mm CL throughout November. During the January–March quarter, the mode became

less discernable, and merged with older age groups. Age group 3 (1979 year class) on the contrary, did not dominate the catch during the year as did age group 3 during the previous year. This age group remained weak until August

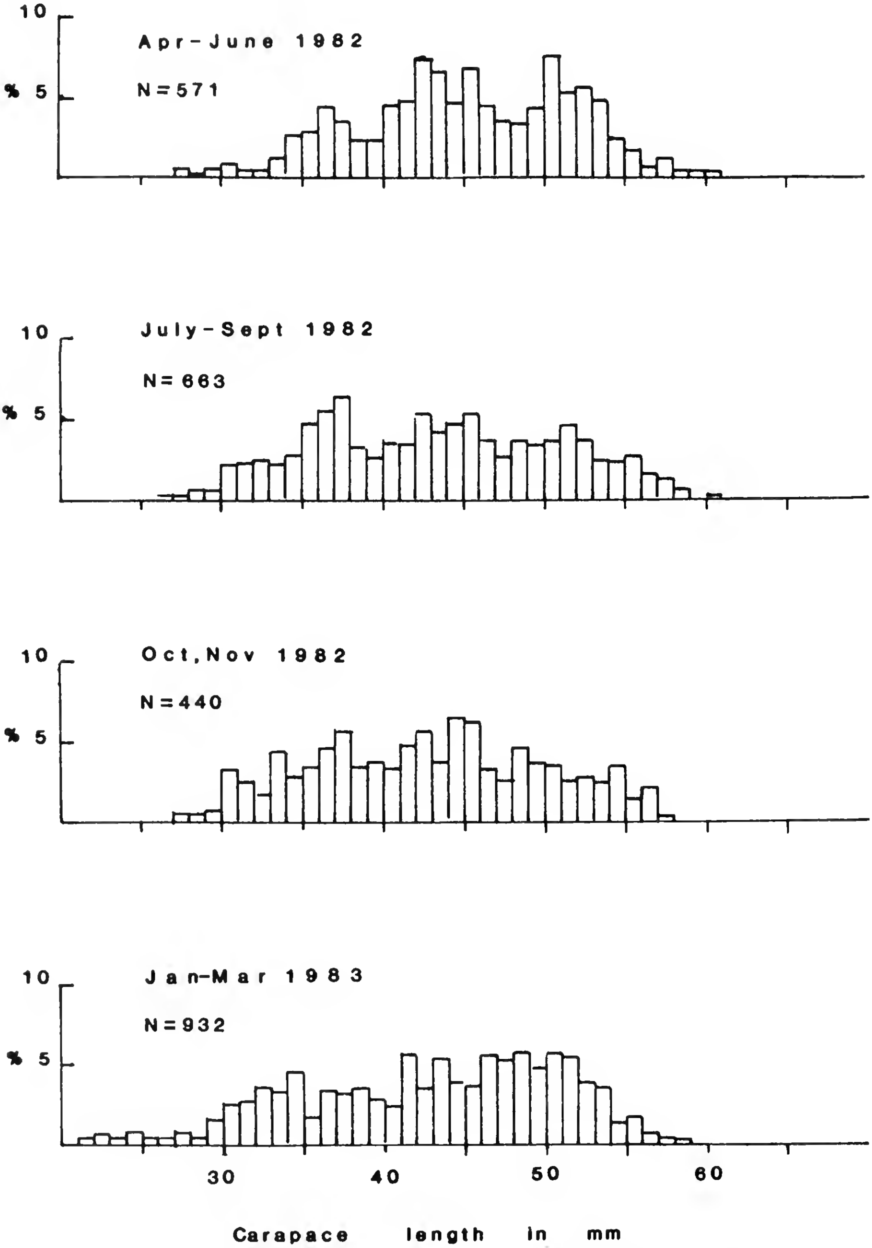

FIGURE 2b. Length frequency distribution of spot prawns during 1981 through 1983.

and the October–November period (Figure 2). During the October–November period, however, recruitment of prawns from the 1980 year class (age group 2) began. These animals averaged 30 mm CL. Their presence continued through the winter, appearing in large numbers during the January–March quarter, and averaging 34 mm CL (Figure 2). Also during this period, prawns from the 1981 year class in the 21–18 mm CL range began appearing (Figure 2).

Von Bertalanffy Growth Calculation

The monthly modes from April 1981 through March of 1982 were incorporated in applying the Von Bertalanffy equation, using the computer program BVG2 (Abramson 1971). A curve was plotted with the following parameters: $L_\infty = 96$ mm CL, $K = 0.157$ and $t_0 = -0.18$. The curve fitted well with the observed length at early ages, although L_∞ occurred much beyond the observed range (Figure 3). Maximum observed age is estimated at 6+ years. This is at least a year older than the previously reported maximum age of 5 years (Butler 1964).

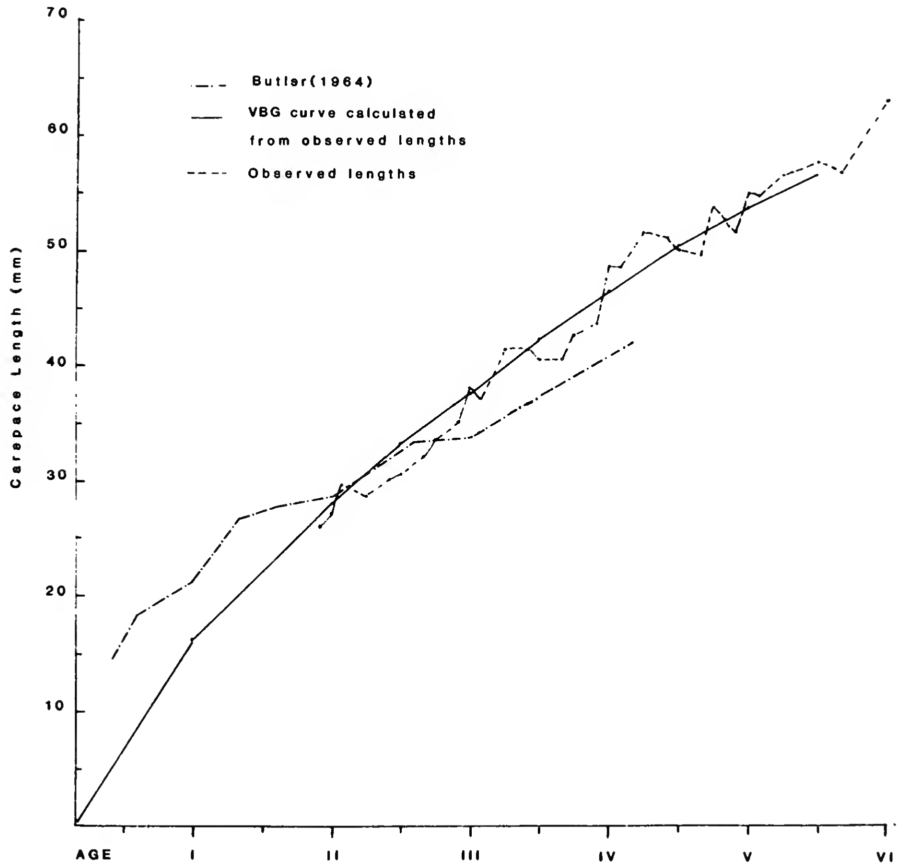

FIGURE 3. Observed and VBG-calculated length at age of spot prawns.

Length-Weight Relationship

Length and weight data in ninety prawns was used to construct a length-weight curve. Size of the prawns ranged from 22 mm CL to 56 mm CL, while weights ranged from 8 g to 102 g (Figure 4). When fitted by the formula $W = a L^b$, the results were $a = 0.00142$, $b = 2.786$ with a correlation coefficient of 0.994 (Figure 4).

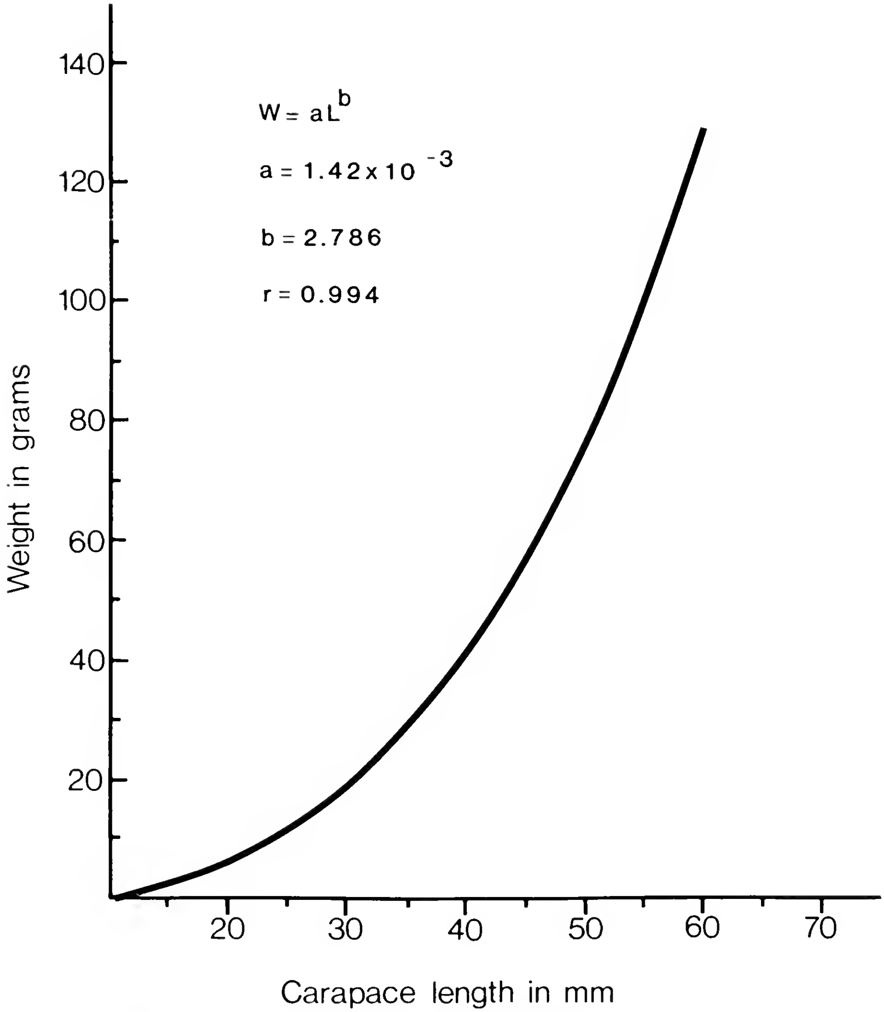

FIGURE 4. Length-weight curve for spot prawns taken from Santa Barbara Channel.

Reproduction

Sexual Development and Maturation

Spot prawns like most pandalid shrimps, are protandric hermaphrodites, beginning their lives as males.

Males became sexually mature during their 4th year when they averaged 40 mm CL. By the end of the 4th year (winter and spring) many males began to change sex into the transitional stage (Figure 5). By summer (5th year) many of the transitionals became females averaging 45 mm CL, although females as small as 39 mm CL were observed (Figure 5).

Ovigerous females began to appear in the samples as early as July, although September appears to be the spawning month as was noted by Butler (1964). By September over 50% of the females were in the ovigerous stage, reaching 100% by December (Figure 6). Females began shedding the eggs during late winter. By April only 15% were ovigerous.

Sex Ratio

These animals, being hermaphroditic, created a problem of determining an appropriate sex ratio. It is expected that males should outnumber females at least by a ratio of 2:1, depending on the dynamics of the population. Sex ratios during the 1981–82 period yielded 2.46 males to 1 female, a reasonable figure, while ratios derived in 1982–83 period fell to 1.34 males to 1 female (Table 1). This unusual occurrence probably was the result of bias in sampling and gear selectivity.

DISCUSSION

The difference in age and growth of spot prawns between areas is quite noticeable. Butler (1964) stated that very few animals from Vancouver lived longer than 4 years, whereas my results indicate that Santa Barbara prawns reach 6 years old. The growth curve of Santa Barbara prawns, based on the Von Bertalanffy equation, also shows a larger length at age for older prawns. Growth rates of the southern stock for the first 3 years follow very closely the results reported by other researchers (Figure 3). But beyond this age, there appeared a divergence, for one season 1981–82, which displayed a larger growth curve. The large variation for 1981–82 data could be attributed to a larger than normal growth of a single year class. Rasmussen (1953) in discussing growth rates of deep sea prawn, *Pandalus borealis,* found that growth rate is dependent upon temperature. In a temperate environment, shrimp grow faster than in a cold environment. *P. jordani,* pink shrimp, also displayed larger size in later ages for shrimp taken in California when compared with Oregon and Washington specimens (Dahlstrom 1963).

Length at sex has also differed between the northern and southern stocks. Berkeley (1930) and Butler (1964) in their studies have shown males to mature at 28–30 mm CL, undergo a transitional stage near 34 mm CL and become females near 37 mm CL. The southern population underwent changes at a larger size, with transitional stages occurring near 45 mm CL and becoming females near 50 mm. Dahlstrom (1963) and Odemar (1964) also observed larger sizes for transitionals and females (43 mm and 47.5 mm CL, respectively). Sexual transformation appears to occur at least a year later for these prawns.

Rasmussen (1967) has noted that growth rates will vary according to the environmental conditions. Perhaps that is the case with the southern stock of spot prawns.

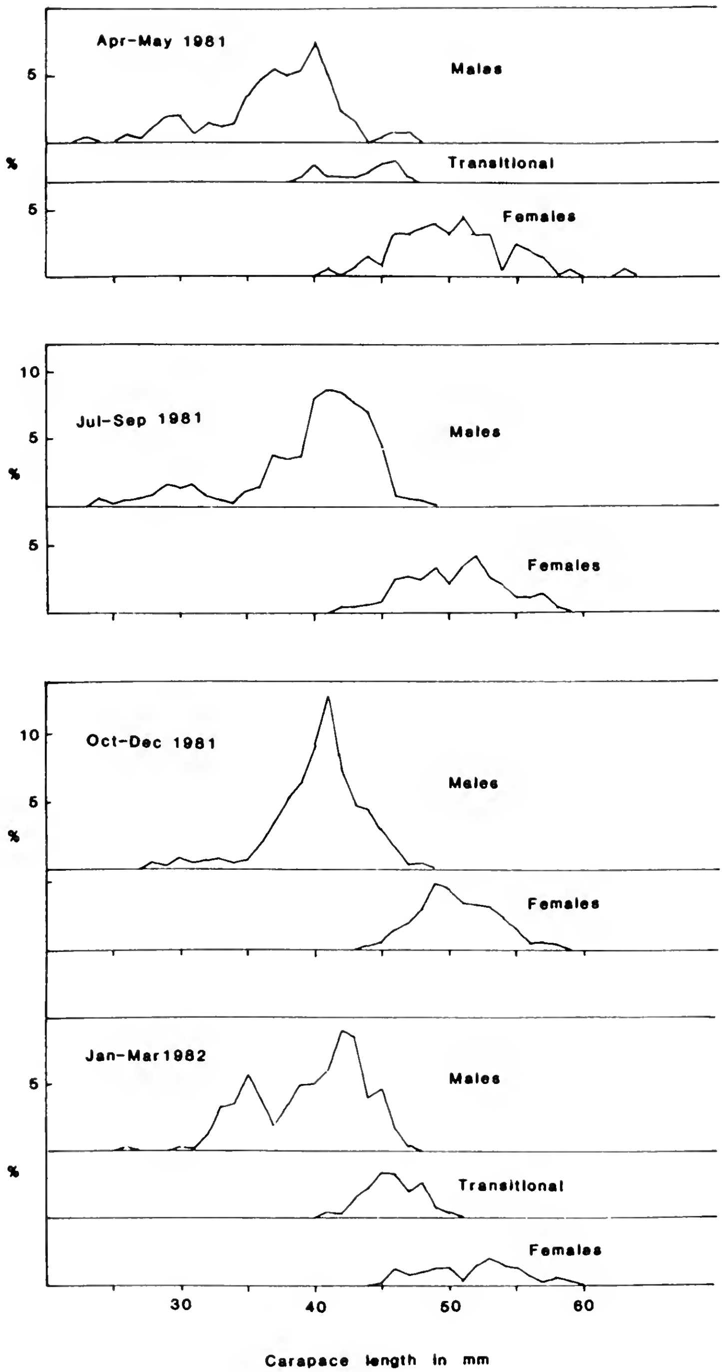

FIGURE 5a. Quarterly length frequency distribution by sex of spot prawns during 1981 through 1983.

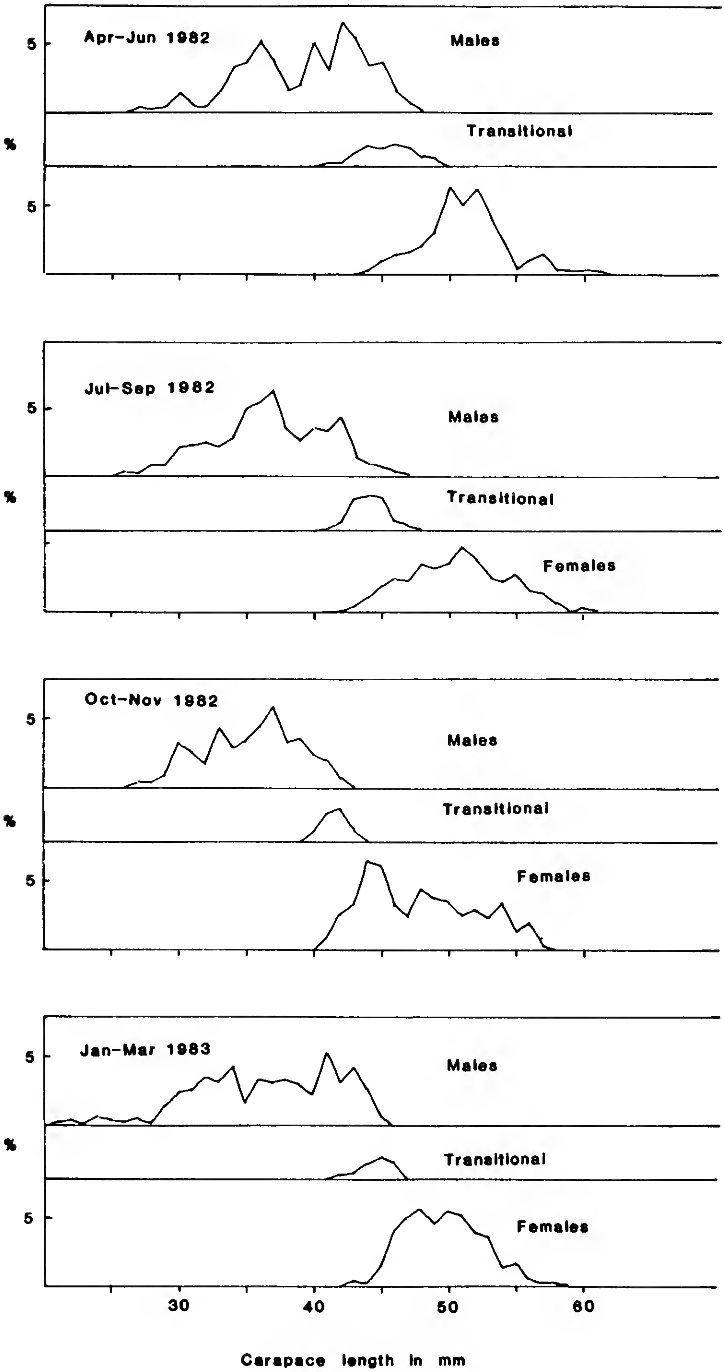

FIGURE 5b. Quarterly length frequency distribution by sex of spot prawns during 1981 through 1983.

TABLE 1. Sex Ratios of Spot Prawns Taken in Santa Barbara Channel.

	1981–82					1982–83			
Month	*No. of males*	*No. of transit.*	*No. of females*	*Ratio M : F*	*Month*	*No. of males*	*No. of transit.*	*No. of females*	*Ratio M : F*
April	107	15	34	3.1:1	April	121	34	95	1.27:1
May	32	5	67	0.47:1	May	no samples	–	–	–
June	no samples	–	–	–	June	93	1	49	1.89:1
July	175	1	109	1.6:1	July	36	0	30	1.2:1
Aug.	no samples	–	–	–	Aug.	182	47	130	1.4:1
Sept.	178	0	58	3.1:1	Sept.	187	16	34	5.5:1
Oct.	210	0	88	2.4:1	Oct.	78	9	69	1.13:1
Nov.	114	0	49	2.3:1	Nov.	123	17	144	0.85:1
Dec.	185	0	107	1.7:1	Dec.	no samples	–	–	–
Jan.	179	41	22	8.1:1	Jan.	283	19	251	1.13:1
Feb.	no samples	–	–	–	Feb.	157	14	121	1.3:1
Mar.	97	26	34	2.85:1	Mar.	38	8	41	0.93:1
Total	1277	88	519	2.46:1	Total	1298	165	964	1.34:1

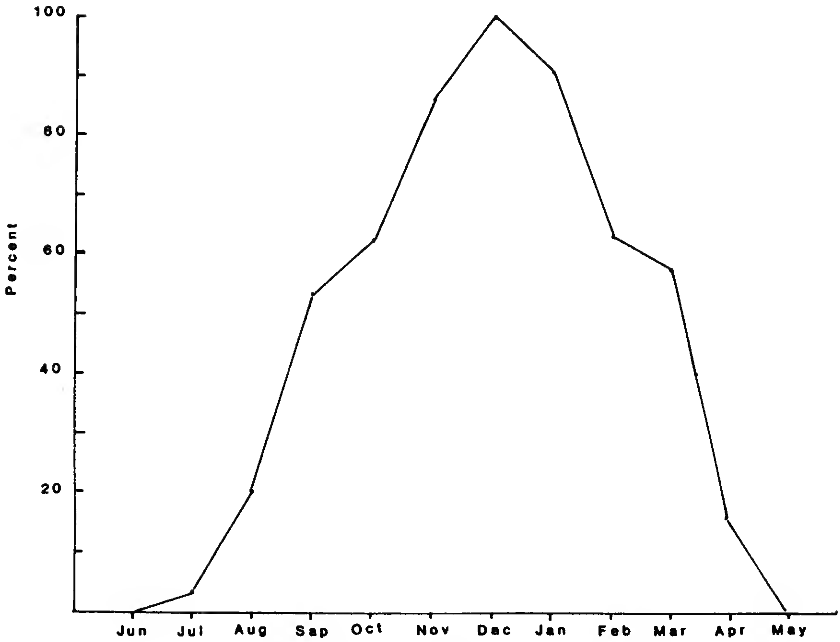

FIGURE 6. Percent of female spot prawn in ovigerous stage by month.

ACKNOWLEDGMENTS

I wish to thank G. Gaona, M. Wagner, J. Richards, and R. Collins for their help and cooperation, and C. Avants for her typing and editorial skills.

LITERATURE CITED

Abramson, J. J. 1971. Computer programs for fish stock assessments. FAO Fish. Tech. Pap., (101):154 p.

Berkeley, A. A. 1930. The post-embryonic development of the common pandalids of British Columbia. Contrib. Canadian Biol., New Series, 6(6):67–163.

Butler, T. H. 1964. Growth reproduction, and distribution of pandalid shrimps in British Columbia. Fish Res. Bd. Canada J., 21 (6):1403–1452.

Cassie, R. M. 1954. Some uses of probability paper in the analysis of size frequency distributions. Australian J. Mar. Freshwater Res., 5:513–522.

Dahlstrom, W. 1963. Cruise Report 63-A-1 Prawn. Dept. Fish and Game. Marine Resources Operation:5 p.

Harding, J. P. 1949. The use of probability paper for graphical analysis of polymodal frequency distributions. J. Mar. Biol. Assoc. U. K., 28:1410153.

Kelly, R. O., A. W. Haseltine, and E. E. Ebert. 1977. Mariculture potential of the spot prawn, *Pandalus platyceros* Brandt. Aquaculture, 10:1–16.

Odemar, M. 1964. Cruise Report 64-A-1 Prawn. Dept. Fish & Game, Marine Resources Operations. 4 p.

Rasmussen, B. 1953. On the geographical variations in growth and sexual development of the deep sea prawn (*Pandalus borealis* Kr) Fiskeridir Skr. Havunders, 10(3):160 p.

————. 1967. Variations in the protandric hermaphroditism of *Pandalus borealis*. Proceedings of the World Scientific Conference on the biology and culture of shrimps and prawns. FAO, Fish. Rept., 57(3):1101–1106.

Calif. Fish and Game 72(2): 94–98 1986

FAWN REARING HABITAT OF THE LAKE HOLLOW DEER HERD, TEHAMA COUNTY, CALIFORNIA [1]

HEATHER J. WELKER
8312 Riata Drive
Redding, California 96002

A four year study was begun in 1980 to identify and describe fawn rearing habitat of the migratory Lake Hollow deer herd in California. The average home range of eight fawns was 14.03 ha with home range sizes for male fawns ($\bar{x}$=23 ha) over twice that of female fawns ($\bar{x}$=11 ha). Thirty-four fawn capture sites and 20 randomly selected sites were used as the centers for circular vegetation plots. Factor analysis revealed significant differences between fawn-selected and random plots, with fawns selecting for higher elevations and areas with taller trees. Seventy-six percent of the fawn locations occurred in ponderosa pine, *Pinus ponderosa,* dominated forests. Key habitat elements occurring in fawn plots include white fir trees, *Abies concolor,* gooseberry, *Ribes* sp., and snowbush, *Ceanothus cordulatus,* shrubs and stumps or dead and down logs.

INTRODUCTION

The mule deer, *Odocoileus hemionus,* is an adaptable cervid occupying at least 57 of the 60 different vegetation types found west of the 100th meridian (Wallmo 1981). The Columbian black-tailed subspecies, *O. h. columbianus,* occurs along the west coast from southern British Columbia to central California. Since the late 1950's deer herds in the western United States have shown a general pattern of decline (Phelps 1976). Because high neonatal fawn mortality occurs in many populations, unsuitable rearing habitat, as it pertains to fawn survival, has been suggested as the reason for much of this decline (Salwasser 1976*a*).

As part of a larger study conducted by the California Department of Fish and Game, a four year study was begun in 1980 to identify and describe fawn rearing habitat of the migratory Lake Hollow deer herd in California. Fawn rearing habitat is defined as the home range, including dropsite, of a fawn during the first two months of life. Funding, equipment, and manpower for the first two years of this four year study were supplied by the California Department of Fish and Game under contract with the Department of Water Resources.

STUDY AREA

The study area was located in Mendocino National Forest in western Tehama County, 40 km southwest of Red Bluff. Fawn work concentrated on a 10 km^2 area of the summer range of this deer herd. The summer range (mean elevation: 2135 m) consists of a mixed conifer forest that receives an average of 153 cm of precipitation annually, most of which is in the form of snow. Temperatures range from -20.6° to 32.2° C. Topography varies from gentle slopes to steep canyons of the major and minor drainages. This specific study area was chosen because of high seasonal deer concentrations and the variety of habitat types.

The area has a history of multiple use. Recreation, particularly in the form of hunting, predominates during the fall months. Several major timber cuts have

[1] Accepted for publication November 1985.

occurred since 1969. Selective timber cuts prevailed, but clear cutting and reseeding techniques also have been used. Sheep grazing dominated the area prior to 1920, but cattle and horses have utilized the area since.

METHODS

Thirty-four fawns were captured between June 1980 and August 1982. All fawns were tagged with numbered aluminum ear tags and 16 were fitted with radio collars (Telonics, Mesa, AZ). Fawn capture sites were used as the centers for circular vegetation plots. A 0.04 ha plot was used, and mature trees were recorded by species, number, height, diameter at breast height (dbh) and percent canopy cover. The number of seedlings and saplings were noted according to species, and the length, diameter, and decay class (Thomas 1979) of dead and fallen trees were recorded. Using the same center point, a second 0.016 ha plot was evaluated for slash content, as well as species, stem number and percent cover of shrubs. Analyses of herbaceous vegetation and estimates of percent cover of litter, bare ground and rock were made within 1 m^2 plots located at the four cardinal directions inside the edge of the 0.04 ha plot. Additional data collected included: aspect, elevation, soil type, indicator species, successional stage (Thomas 1979) and the distance to roads, water, and special features such as meadow.

Twenty random plots representing available habitat were selected using a grid and random number table and evaluated in the same manner as fawn selected plots. Comparisons between random selected and fawn selected sites were used to identify specific fawn use habitat components. Each habitat component was examined individually to determine if usage occurred in a clumped, random or uniform distribution. Factor analysis, as described in the *Statistical Package for the Social Sciences* (SPSS 1975), was used to detect important variables for each individual year and for all three years combined.

RESULTS

Home range data were collected on eight fawns: two in 1980 and six in 1981. This sample included six females and two males. The fawns were tracked from their first week after birth to ages ranging from 48 to 98 days. Based on 631 telemetric point locations (17–177 per fawn), the average home range size for these fawns was 14.0 ha (range=1.1–26.0 ha). The average home range size for male fawns ($\bar{x}$ =23 ha) was over twice that of female fawns ($\bar{x}$ =11 ha).

Seventy-six percent of the fawn locations occurred in ponderosa pine dominated forests with Douglas fir, *Pseudotsuga menziesi,* as a codominant tree. Fourteen percent of the locations occurred in habitats where Douglas fir was the principal tree species and seven percent occurred in areas dominated by white fir. Three percent of the locations were in miscellaneous shrub habitats. Crown diameters in the forested habitats were mainly 8 to 12 m and almost 48% of the fawn locations occurred in areas with 20% to 39% crown cover.

From the analysis of 64 variables representing fawn capture sites in all three years combined, 29 variables produced four main group associations (Table 1). Each variable group is a part of a community where fawns may be expected to occur.

TABLE 1. Means and (Standard Deviations) of Important Variables According to Group for 1980–1982

Group I Variables			
Mature trees	*Trees/ha*	*Height (m)*	*dbh (m)*
Douglas fir	22.8 (64.0)	7.8 (18.9)	.2 (.5)
Sugar pine	19.9 (53.2)	8.5 (16.8)	.2 (.3)
Seedlings/Saplings			
Ponderosa pine	41.0 (108.8)		
Sugar pine	16.9 (35.0)		
Shrubs	*Stems/ha*	*Percent canopy*	
Manzanita	14.7 (48.8)	1.2 (6.0)	
Elevation	1795.1 (78.4)		
Group II Variables			
Shrubs	*Stems/ha*	*Percent canopy*	
Snowberry	275.7 (546.9)	.7 (1.3)	
Rose	79.0 (303.1)	7.6 (17.6)	
Distance to Road (m)	60.2 (135.6)		
Group III Variables			
Mature trees	*Trees/ha*	*Height (m)*	*dbh (m)*
Incense cedar	19.9 (64.8)	5.4 (12.2)	.1 (.3)
Seedlings/Saplings			
White fir	171.3 (363.3)		
Incense cedar	52.2 (147.5)		
Decay Class	*Logs/ha*	*Length (m)*	*Diameter (m)*
5	7.4 (20.0)	.6 (1.3)	.1 (.3)
Group IV Variables			
Seedlings/Saplings		*Trees/ha*	
Douglas fir		34.5 (85.0)	
Shrubs	*Stems/ha*	*Percent canopy*	
Snowbush	698.5 (1883.1)	7.6 (17.6)	
Herbaceous			
Phlox	23,235.0 (77,000.0)	.7 (.3)	

Group I Variables

Sugar Pine—Douglas Fir

Overstory canopy averaged 8.1 m in height and was dominated by sugar pine, *Pinus lambertiana,* and Douglas fir trees. Understory consisted largely of sugar pine and ponderosa pine seedlings and saplings as well as green-leaf manzanita, *Arctostaphalos viscida,* shrubs. This type of community was found at approximately 1795 m elevation.

Group II Variables

Snowberry—Rose

Snowberry, *Symphoricarpos albus,* and rose, *Rosa* sp., shrubs were typically found together in habitats at distances over 60 m from a road.

Group III Variables

Incense Cedar

Overstory was incense cedar, *Libocedrus decurrens,* and averaged 5.4 m in height. Young white fir and incense cedar trees formed the understory. Approximately 7.4 old (decay class 5) logs (Thomas 1979) were found per hectare.

Group IV Variables

Douglas Fir Seedlings and Saplings

Seedlings and saplings of Douglas fir were associated with snowbush shrubs and the herbaceous plant, phlox, *Polemonium californicum.*

Fifty-seven variables were used in the analysis comparing random and fawn-selected plots. Mature trees of all species were significantly ($P<0.05$, $t=2.65$) taller in fawn-selected plots ($n=34$) than in randomly selected plots ($n=20$). This single factor could promote shrub cover on the forest floor, a key element in fawn plots. Fawns also were found at significantly ($P<0.05$, $t=2.94$) higher elevations ($\bar{x} = 1795.2$ m, range$=$1493.5–1950.7 m) than were random plots ($\bar{x} = 1732.0$ m, range$=$ 1584.9–1859.3 m). This is not surprising since fawns have been known to select for ridge top areas (Russo 1964), possibly as a mechanism for predator avoidance.

The herbaceous plants phlox and mullein, *Verbascum thapsus,* seemed to appear more commonly in fawn selected sites, as did the shrubs snowbush and gooseberry. White fir trees (both mature and young) also seemed to occur predominantly in fawn selected sites. However, these differences were not statistically significant.

In this study, 76.5% of the fawns captured were found lying adjacent to either a stump, down tree, or the base of a standing tree (snag or alive). Although none of the fawns in this study were found in meadows, several were found nearby. This suggests potential use of meadow edge type habitats.

DISCUSSION

Heterogeneity seems to be the key to fawn rearing habitat. Forest management should strive for intermediate successional stages with a habitat mosaic ranging from shrub-seedling to mature tree associations. Selection for subclimax vegetation has been noted in several studies (Townsend and Smith 1933, Bartush and Lewis 1981). Subclimax forests provide various browse species as well as a diversity of concealment cover. Multi-level vegetation also can be important in terms of sunlight scattering on the forest floor. This may be especially important in aiding the concealment of spotted fawns (Holl unpublished data).

There is much evidence noting the close association between young fawns and shrub cover (Michael 1964, Trainer 1972, Kie 1980, Dood unpublished data). The frequency of gooseberry and snowbush shrubs in fawn selected plots has also been previously recorded (Holl unpublished data). Healthy shrubs and forbs, as maintained by prescribed burning, can restore decadent vegetation into prime cover and browse. Logging opens up forests, but burning provides quality in the vegetation (Salwasser 1976*b*).

The kind and extent of woody material determines its usefulness. Heavy slash has proven to be a hindrance (Thomas 1979), especially to small fawns, and should be removed or thinned out from heavily used areas such as major migration trails. Some slash can be useful as cover. Reynolds (1966) suggests that deer may feel more conspicuous in areas cleared of slash. The use of large tree debris by fawns was found not only in the present study, but past studies as well (Salwasser 1972, Wallmo 1981). Snags, as well as large pieces of dead and down material can be flagged for protection during logging and burning operations. Early spring burns remove small, dry, woody material from the forest floor while allowing the larger more moist logs to remain protected. Trees can be girdled in heavily forested areas to produce snags. A uniform carpet of woodchips greater than 2.5 cm in thickness adversely affects seedling, shrub and herbaceous plant development (Thomas 1979).

Use of meadow habitats by fawns has varied (Salwasser 1972, Holl unpublished data). Taylor (1956) found that fawns readily used meadow margins as they did in the present study, suggesting that buffer zones of unlogged forest at least 40 m wide should be maintained on all sides of meadow habitats within key fawning areas.

ACKNOWLEDGMENTS

I am grateful to the California Department of Fish and Game for their cooperation and partial funding of this research project. In particular, I wish to thank J. Siperek and C. Mayor for their help and support during the initial stages of this study. I would like to thank G. Stewart for his time and assistance in the completion of this manuscript and for his continued support. Finally, I would like to give special recognition to my field assistants, friends, roommates and my family who aided in data collection, support and patience through out this project.

LITERATURE CITED

Bartush, W.S., and J.C. Lewis. 1981. Mortality of white-tailed deer fawns in the Wichita Mountains. Proc. Okla. Acad. Science, 61:23–27.

Kie, J. 1980. Deer response to Trinity River habitat manipulation Part II. Coop. Study USDA Forest Service and Univ. of Cal., Davis. 10 pp.

Michael, E.D. 1964. Birth of white-tailed deer fawns. J. Wildl. Manage., 28(1):171–173.

Phelps, J.E. 1976. Introduction to conference on mule deer decline in the west, a symposium. Utah State Univ. Logan, Utah.

Reynolds, H.G. 1966. Slash cleanup in a ponderosa pine forest affects use by deer and cattle. U.S. Forest Service Research Note RM-64.

Russo, J.P. 1964. The Kaibab North Deer Herd-its history, problems and management. State of Arizona Game and Fish Dept. Phoenix, Ariz. Wildl. Bull., No. 7.

Salwasser, H.J. 1972. North Kings Deer Herd fawn production and survival study. Cal. Dept. Fish and Game. PR. W-51-R-17.

________1976*a*. Proceedings of the September 1975 interstate deer herd technical committee seminar. Interstate Wildl. Study Newsletter No. 4.

________1976*b*. Status and trend of the Devil's Garden Interstate Mule Deer Herd, 1975. Interstate Wildl. Study Newsletter No. 4.

SPSS-Statistical Package for the Social Sciences. 1975. Control Data Corporation and Northwestern University. Minneapolis, Minn. 675 pp.

Taylor, W.P. 1956. The deer of North America. Stackpole Company, Washington. 668 pp.

Thomas J.W. 1979. Wildlife habitats in managed forests. Washington, D.C. 512 pp.

Townsend, M.T., and M.W. Smith. 1933. The whitetail deer of the Adirondacks. Bul. N.Y. State College. Forestry Syracuse Univ., 6(1):153–385.

Trainer, C.E. 1972. Fawn marking and monitoring. Steens Mountain Mule Deer Population Study. Study IV, Job 4-R.

Wallmo, O.C. 1981. Mule and black-tailed deer of North America. Univ. of Nebraska Press, Lincoln, NE. 605 pp.

Calif. Fish and Game 72(2): 99–102 1986

FAWN MORTALITY IN THE LAKE HOLLOW DEER HERD, TEHAMA COUNTY, CALIFORNIA [1]

HEATHER J. WELKER
8312 Riata Drive
Redding, California 96002

Twenty-eight fawns were captured in Tehama County, California between June 1980 and August 1983 to determine direct causes of fawn mortality and to identify factors contributing to fawn survival. Fawn characteristics and initial health were recorded. Sixteen fawns were fitted with motion-sensitive radio collars. Fifty-six percent of the fawns survived through fall migration. The average age at death was 41 days. Four of the seven radio-collared fawn mortalities were attributed to predation with the three additional fawns succumbing to starvation, accident and an unknown cause.

INTRODUCTION

The problem of neonatal fawn survival in mule deer, *Odocoileus hemionus,* has become an increasing concern since the late 1950's when many western deer herds began a general pattern of decline. Schneegas and Bumstead (1977) did not believe that a variety of traditional factors, including drought, over-hunting, winter loss, predation and disease, "would impact such a broad, diverse area to the same degree, at the same time". They concluded that neonatal fawn loss was keeping population numbers down.

High fawn mortality has become the limiting factor in many western deer herds (Carroll and Brown 1977, Steigers and Flinders 1980) with summer losses recorded as high as 90 percent (Carroll and Brown 1977, Bartush and Lewis 1981).

As part of a larger study conducted by the California Department of Fish and Game, a two year investigation was begun in 1980 to determine direct causes of fawn mortality and to identify factors contributing to fawn survival in the migratory Lake Hollow deer herd in California. Funding, equipment, and man-power for field research were suppplied by the California Department of Fish and Game under contract with the Department of Water Resources.

STUDY AREA

The study area was located in Mendocino National Forest in western Tehama County, 40 km southwest of Red Bluff. Fawn work concentrated on a 10 km^2 area of the summer range of this deer herd. The summer range (mean elevation: 2135 m) consists of a mixed conifer forest that receives an average of 153 cm of precipitation annually, most of which is in the form of snow. Temperatures range from −20.6° to 32.2° C. Topography varies from gentle slopes to steep canyons in the major and minor drainages. This specific study area was chosen because of high seasonal deer concentrations and the variety of habitat types.

METHODS

Sixteen Columbian black-tailed fawns (*O.h. columbianus*) were captured, tagged with numbered aluminum ear tags and fitted with expandable, motion

[1] Accepted for publication December 1985.

sensitive radio-transmitter collars, (Telonics, Mesa, AZ). Five fawns were captured in 1980 and 11 fawns in 1981. The collars weighed approximately 227 g and had a life expectancy of 18 months. Each fawn was monitored from birth to death, or up to and including fall migration. A collar which remained immobile for six hours or more doubled its pulse rate, signalling either a dropped collar or a mortality. Once a death mode signal was received, an attempt was made to locate the carcass and, when possible, a necropsy form (Salwasser and Jessup 1978) was completed. Investigation involved search of the immediate area for evidence of the cause of death. Criteria for the cause of death followed those found in several other studies (Cook et al. 1971; Bowns 1976; Garner, Morrison and Lewis 1976).

RESULTS

The average summer fawn loss for radio-collared fawns (late June to early October) in this study was 44%. The average age at death was 41 days (n=7, range=3–98 d).

Four of the seven fawn deaths were attributed to predation. The average age of fawns killed by predators was 52 days. Two female fawns at 54 and 48 days of age were killed by mountain lions, *Felis concolor.* Both carcasses were found buried with mountain lion tracks in the vicinity. A third predator kill involved a male fawn, seven days of age. Tracks resembling those of a cat were located, but positive identification could not be made. One buck fawn died at 98 days of age. Remains included a blood-stained radio collar with both black bear, *Ursus americana,* and coyote, *Canis latrans,* scats nearby.

One male fawn was orphaned at 24 days of age when its radio-collared dam was killed by coyotes. The orphan lived to 54 days of age. Stomach contents consisted of grasses with no milk curds. Carcass weight (2.6 kg) was less than the capture weight (4.0 kg) taken three days prior.

The last identifiable mortality involved a three-day-old male fawn. Necropsy revealed a broken neck. The fawn was found in heavy timber slash, less than 275 m from where it had been captured the previous day. Only adult deer and fawn tracks were found in the vicinity.

One additional male fawn died from unknown causes. Remains consisted only of a blood-stained radio collar.

DISCUSSION

Causes of mortality are numerous and often difficult to assess. For example, weakness, as would result from malnutrition, infection or injury, may encourage predation. Vulnerability to predation also may increase with enhanced stress, diarrhea, elevated body temperature and body fluid discharges (Cook et al. 1971). Other mortality factors that can be important but difficult to identify and evaluate are starvation, disease, human disturbance, accidents, and abandonment. Several causes for abandonment include poor habitat (White, Knowlton and Glazener 1972), primiparious does (Smith unpublished data), fawns too weak to nurse (White et al. 1972) and the effects of marking and handling (Trainer 1972, White et al. 1972).

Fawn behavior also has been considered a cause of mortality. The greater activity and curiosity of male fawns can result in a sex-biased mortality rate (Taber and Dasmann 1954, Brown 1961, Steigers and Flinders 1980). Three of

the 11 radio-collared female fawns and all five of the male fawns in the present study did not survive to complete fall migration.

Habitat has a definite impact on fawn survival (Taber and Dasmann 1954, Welker 1984). Reduction in habitat quality during the last trimester of gestation and during lactation can result in does in poor condition and in weak, underweight fawns (Taber and Dasmann 1958; Salwasser, Holl, and Ashcraft 1978). Proper weaning forage is important for growing fawns. Healthy shrubs and forbs are needed for camouflage against predators and for thermoregulation. Sparse ground cover can result in a reduction in alternate prey species (rodents and rabbits) increasing predator pressure on fawns (Smith and LeCount 1976).

It should be noted that marking fawns for future recognition can lead to increased mortality of the marked individuals. Ear tags can reduce camouflage and cause more frequent ear movements, attracting predators (White et al. 1972). Goldberg and Haas (1978) found hesitant acceptance of fawns by their dams. Trainer (1972) considered ear tags and streamers to be, possibly, the most serious hindrance to a monitored fawn's survival. Some investigators (Cook, White, Trainer and Glazener 1967; Cook et al. 1971; Bartush and Lewis 1981) have not found a significant difference in mortality rates between collared and noncollared fawns, and no evidence was obtained on this subject in the present study. However, biologists who mark fawns should be aware of the potential importance of their study techniques.

The importance of fawn production and survival in maintaining a healthy deer population is obvious. Still, the factors which pose the greatest threat to fawn survival remain unclear. Predation may have a larger impact on deer populations than once believed. With the justification for short-term predator removal in question, factors promoting high levels of predation may be the target for management action. Hornocker (1976) suggests that if suitable habitat is not available for the prey species then no matter how extensive the predator control, significant return of the prey population will not occur. He also states that prey numbers at an already low level can be greatly affected by virtually any depressing factor. Thus, a well planned and ecologically sensible program of habitat management may be the most rewarding approach to minimizing fawn mortality.

ACKNOWLEDGMENTS

I am grateful to the California Department of Fish and Game for their cooperation and partial funding of this research project. In particular, I wish to thank J. Siperek for initiating this study and for his help and support with data collection. I would like to thank G. Stewart for his time and assistance in the writing of this manuscript. Finally, I would like to acknowledge my field assistants, friends, roommates and especially my family who aided in data collection, support and patience throughout this project.

LITERATURE CITED

Bartush, W.S., and J.C. Lewis. 1981. Mortality of white-tailed deer fawns in the Wichita Mountains. Proc. Okla Acad. Science, 61:23–27.

Bowns, J.E. 1976. Field criteria for predator damage assessment. Utah Science., 37:26–30.

Brown, E.R. 1961. The black-tailed deer of western Washington. Washington State Game Dept. Bio. Bull., No. 13

Carroll, B.K., and D.L. Brown. 1977. Factors affecting neonatal fawn survival in southern-central Texas. J. Wildl. Manage., 41(1):63–69.

Cook, R.S., M. White, D.O. Trainer, and W.C. Glazener. 1967. Radiotelemetry for fawn mortality studies. Bull. Wildl. Disease Assoc., 3:160–165.

Cook, R.S., M. White, D.O. Trainer, and W.C. Glazener. 1971. Mortality of young white-tailed deer fawns in south Texas. J. Wildl. Manage., 35(1):47–56.

Garner, G.W., J.A. Morrison, and J.C. Lewis. 1976. Mortality of white-tailed deer fawns in the Whichita Mountains, Oklahoma. Southeastern Assoc. of Game and Fish Comm. 13th Annual Conf. 30.

Goldberg, J.S., and W. Haas. 1978. Interactions between mule deer dams and their radio-collared and unmarked fawns. J. Wildl. Manage., 42(2):422–425.

Hornocker, M. 1976. The possible influence of the mountain lion on mule deer populations. Mule Deer Decline in the West, A symposium. Utah State University, Logan, Utah pp. 107–109.

Salwasser, H.J., S. Holl, and G. Ashcraft. 1978. Fawn production and survival in the North Kings River Deer Herd. Calif. Fish Game, 64(1):38–52.

Salwasser, H.J., and D. Jessup. 1978. A methodology for performing necropsies and data analysis on road-killed deer. Unpubl. Report. Univ. of Cal., Berkeley and Cal. Dept. of Fish and Game. 19 pp.

Schneegas, E.R., and R.S. Bumstead. 1977. Decline of western mule deer populations: probable cause, tentative solution. Western Proc. 57th Ann. Conf. of the West. Assoc. of State Game and Fish Comm. 57.

Smith, R.H., and A. LeCount. 1976. Factors affecting survival of mule deer fawns. AZ Game and Fish Dept. Fed. Aid in Wildl. Rest. Proj. W-78-R.

Steigers, W.D., and J.T. Flinders. 1980. Mortality and movements of mule deer fawns in Washington. J. Wildl. Manage., 44(2):381–388.

Taber, R.D., and R.F. Dasmann. 1954. A sex difference in mortality in young Columbian black-tailed deer. J. Wild. Mange., 18(3):309–315.

________. 1958. The black-tailed deer of chaparral. Cal. Dept. Fish and Game. Game Bull. No. 13.

Trainer, C.E. 1972. Fawn marking and monitoring. Steens Mountain Mule Deer Population Study. Study IV, Job 4-R.

Welker, H.J. 1984. Fawn rearing habitat of the Lake Hollow Deer Herd, Tehama County, California. In Press.

White, M., F. Knowlton, and W.C. Glazener. 1972. Effects of dam-newborn fawn behavior on capture and mortality. J. Wildl. Manage., 35(3):897–906.

Calif. Fish and Game 72(2): 103–109 1986

MOVEMENT OF TWO NEARSHORE, TERRITORIAL ROCKFISHES PREVIOUSLY REPORTED AS NON-MOVERS AND IMPLICATIONS TO MANAGEMENT [1]

KATHLEEN R. MATTHEWS [2]
Moss Landing Marine Laboratories
Box 223
Moss Landing, California 95039

Movement up to 1.2 km was noted for two nearshore, territorial rockfishes, *Sebastes carnatus* and *Sebastes chrysomelas,* previously reported as non-movers. These adult rockfishes moved from low relief natural reefs to an artificial reef. Six *Sebastes carnatus* and four *Sebastes chrysomelas* were recaptured on the artificial reef after having been tagged on the natural reefs demonstrating movement of at least 0.8 km. The fishes ranged in size from 24–29 cm (TL) and were at liberty 28–372 days before recapture. This is the longest substantiated movement reported for these two species. More movement of rockfishes may occur away from low relief rocky reefs as these reefs may have less shelter holes available to support territorial rockfishes compared to high relief reefs. In addition, these two species of rockfishes were caught by hook-and-line fishing in significantly higher proportions than were observed on underwater transects suggesting that some aspect of their territorial or aggressive behavior makes them more prone to sportfishing. Movement to higher relief artificial reefs, high vulnerability of these relatively nonabundant fishes to sportfishing, combined with the fact that artificial reefs generally receive substantial fishing pressure could subject these species to overfishing. These factors need to be considered for effective management of territorial rockfishes.

INTRODUCTION

Rockfishes, of the genus *Sebastes,* are a very diverse group with over 100 species worldwide (Lea 1983). The eastern North Pacific has approximately 70 species that range bathymetrically from the intertidal to the edge of the continental shelf. Their movement patterns also vary, with most shallow water benthic rockfishes being considered to be either non-movers or to at least be residents of one reef system (Miller and Geibel 1973, Love 1978, Love 1983). Larson (1980*a*), in a diving study in southern California, reported the black-and-yellow rockfish (S. *chrysomelas*) and gopher rockfish (S. *carnatus*), which are heavy bodied and demersal, to exhibit aggressive behavior and limited movement. Both of these solitary species are shallow water rocky reef residents with overlapping geographic ranges; Baja California to Eureka, California (Miller and Lea 1972). Larson (1980*b*) also described these fishes as perennially territorial with most individuals setting up vigorously defended shelter holes.

Although many studies indicate that nearshore benthic rockfishes are non-movers, it has been reported that their densities decrease during the winter months and sometimes at night. Moulton (1977) found higher densities of solitary rockfishes during the summer months while Larson (1980*c*) found counts of black-and-yellow and gopher rockfishes to vary seasonally with highest numbers occurring in summer and fall. While Larson suggested that the fishes were more difficult to see underwater during the winter months, resulting in

[1] Accepted for publication December 1985.

[2] Current address: School of Fisheries, Fisheries Research Institute, University of Washington, Seattle, Wa. 98195, Contribution No. 683. School of Fisheries, University of Washington, Seattle, Wa. 98195.

lower observed densities, another explanation could be that they had simply moved off the reef. These rockfishes could also be moving at night when they become more active (Ebeling and Bray 1976, Larson 1980*c*) or during storms when diver observation is restricted.

Recently, Hallacher (1984) found movement up to 50 m for translocated black-and-yellow rockfish moving back to their home sites and suggested that this species may be more mobile than previously thought. Hallacher at first thought this homing behavior to be paradoxical in a territorial species but suggested that homing cues could be retained from recruitment or life as a non-territory holder. Whatever the mechanism, this information does suggest that if black-and-yellow rockfish do move away from their home site, for any reason, they have the ability to find their way back.

Other paradoxical information regarding the movement of rockfishes is the widely documented phenomenon of adults of territorial species colonizing newly created artifical reefs, obviously moving from somewhere (Walton 1979, Solonsky 1985). Are the rockfishes that colonize artifical reefs, or other newly established habitat, moving away from established shelter holes or are they without territories? Larson (1980*a*) showed that when black-and-yellow rockfish were removed from the shallow, more desirable habitat, that normally deeper living gopher rockfish would move in to establish new territories. Some of the gopher rockfish had left established territories indicating that some roaming does occur in this species enabling their location of the recently vacated shelter holes. Thus, it appears that some movement will take place in fishes with established territories in the pursuit of better habitat.

Clearly, movement patterns of rockfishes are more complicated than previously thought. Although they may be capable of returning to their original habitat after roaming about at night or during the winter, some may set up new territories if a more desirable one is found. Evidence indicates that at least some limited movement does occur in these "sedentary" rockfishes and while I was studying movement of fishes between natural and artificial reefs I documented movement up to 1.2 km for black-and-yellow and gopher rockfishes, substantially farther than previously reported. The objectives of this paper are to: i) describe the field data in which the movements of black-and-yellow rockfish, *Sebastes chrysomelas,* and gopher rockfish, *Sebastes carnatus,* are reported, and ii) discuss these results and their implications.

MATERIALS AND METHODS

Study Site

The Capitola artificial reef, located in northern Monterey Bay, was funded by the Wildlife Conservation Board of California and the location was chosen by the California Department of Fish and Game. It was placed in the water during August 1981 and is located 1.3 km south of the Capitola pier (Figure 1) at latitude 36°56.7′N, longitude 121°57.3′W. The reef lies in 13.7 m of water on sand covered mudstone and is marked with a 3 m buoy designating it as an artificial reef. The reef consists of 240 concrete pipes and covers an area of 1200 m^2 (Table 1). The pipes have inside diameters of 30–250 cm while the vertical relief of the reef ranges from 0.5 to 5 m.

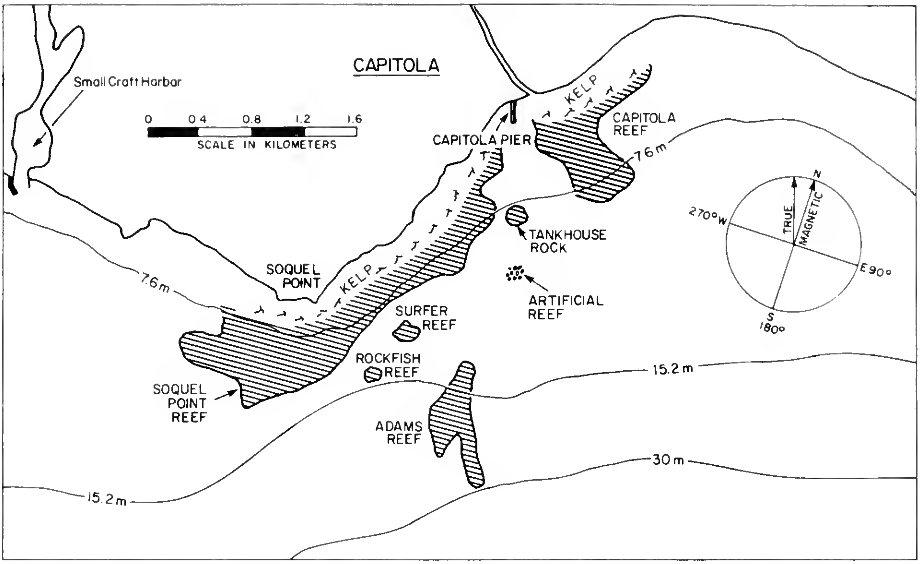

FIGURE 1. Map showing relative location of the artificial and natural reefs.

Table 1. Description of the Natural and Artificial Reefs

	Vertical relief (m)	*Distance (km) and direction from artificial reef*	*Depth (m)*	*Kelp*	*Area (m²)*
Surfer Reef	0–3	0.8 SW	12.2	Yes	5,000
Rockfish Reef	0–3	1.2 SW	15.2	No	5,000
Adams Reef	0–1.5	0.8–1.6 S	24.4–30.5	No	200,000
Tankhouse Rock	0–1	0.8 N	10.7	Yes	4,000
Artificial reef	0–5	—	13.7	No	1,200

The four natural reefs investigated were Surfer Reef, Rockfish Reef, Tankhouse Rock, and Adams Reef (Figure 1) and all were low relief mudstone. Two of the reefs, Surfer and Rockfish, are 0.8 km and 1.2 km southwest of the artificial reef, respectively (Table 1). Surfer Reef is 12.2 m deep, surrounded by sand, and supports a perennial stand of giant kelp, *Macrocystis pyrifera*. Rockfish Reef is 15.2 m deep, is also surrounded by sand, but has no giant kelp. The third reef, Tankhouse Rock, is 0.8 km north of the artificial reef and supports a lush stand of kelp. Tankhouse Rock is 10.7 m deep and like Surfer and Rockfish reefs has little vertical relief (0–3 m). The fourth natural reef, Adams Reef, is 0.8 to 1.6 km south of the artificial reef. It consists of flat rocks interspersed with sand and has a bottom depth ranging from 21.3–27.4 m with little vertical relief (0–1 m). Like the artificial reef, Adams has no kelp. All of the natural reefs are separated from each other and the artificial reef by sandy flats.

Tagging Study

A tagging study was done to determine if movement of fishes occurred between the natural and artificial reefs. Fish were tagged with Floy spaghetti tags that were numbered and color coded for each reef. All fishes were caught using hook-and-line, were identified, measured (cm TL), and had a tag inserted in the anterio-dorsal musculature. Subsequent monitoring of the sportfish catch, our hook-and-line fishing, and underwater observations provided tag recapture data. The tagging project was advertised to the local sportfishermen and a reward system aided in the tag returns. Only the results of black-and-yellow and gopher rockfishes tagged on the natural reefs are reported in this paper (see Matthews 1985 and Solonsky 1985 for additional information).

RESULTS

Out of a total of 51 gopher rockfish tagged on the four natural reefs, nine were recaptured (Table 2). Six of the nine recaptured fish were caught on the artificial reef demonstrating movement of at least 1.2 km. The remaining three gopher rockfish were recaptured on the reefs where they were originally tagged. The fish that moved to the artificial reef ranged in size from 24–29 cm (large adults) and were at liberty from 28–372 days before recapture.

TABLE 2. Summary of Tag-Recapture Information for the Black-and-Yellow and Gopher Rockfishes Tagged on the Natural Reefs.

Fish No.	*Date tagged*	*Days at liberty*	*Movement*	*Distance (Km)*	*Size cm* TL
GOPHER ROCKFISH					
1	2/82	160	Tankhouse to art. reef	0.8	24.0
2	7/82	34	Rockfish to art. reef	1.2	26.0
3	7/82	28	Surfer to art. reef	0.8	25.0
4	4/82	36	Surfer to art. reet	0.8	24.0
5	7/82	34	Surfer to art. reef	0.8	29.0
6	6/82	372	Adams to art. reef	0.8–1.6	28.0
7	5/83	61	Tagged and recaptured on Rockfish	—	28.0
8	9/82	293	Tagged and recaptured on Surfer	—	23.5
9	6/82	361	Tagged and recaptured on Surfer	—	31.0
BLACK-AND-YELLOW ROCKFISH					
1	6/82	50	Tankhouse to art. reef	0.8	26.0
2	3/82	53	Surfer to art. reef	0.8	24.5
3	7/82	13	Surfer to art. reef	0.8	23.0
4	5/82	56	Adams to art. reef	0.8–1.6	28.0
5	5/83	49	Tagged and recaptured on Rockfish	—	25.0

Sixteen black-and-yellow rockfish were tagged on the natural reefs with five being recaptured. Four of the five recaptured fish were caught on the artificial reef demonstrating movement of at least 0.8 km, while one black-and-yellow rockfish was recaptured on Rockfish Reef where it was originally tagged. The fish recaptured on the artificial reef ranged in size from 23–28 cm (large adults) and were at liberty from 13 to 56 days (Table 2).

DISCUSSION

The movements documented are the longest yet reported for black-and-yellow and gopher rockfishes. Moreover, the fishes had to travel over wide expanses of sand to reach the artificial reef from the natural reefs where they were originally tagged. Thus, in agreement with Hallacher (1984) it appears that some territorial rockfish species move about more than previously thought. The movement patterns of rockfishes are intriguing and deserve more attention to fully understand the reasons and implications.

Despite the wealth of information concerning territoriality in birds and tropical families of fishes, this subject has only recently been investigated in temperate fishes (Hallacher 1977, Larson 1980*a*, Hixon 1981). Larson (1980*a*) described both floater and commuter rockfishes living on the same reef with strictly territorial black-and-yellow and gopher rockfishes. Commuters were those that had separate shelter and feeding areas but were not very mobile, only moving up to a few meters. Some of the commuters were quite large ($\bar{x}=184$ mm SL) being approximately 3–4 years old. Floaters were described as moving about a great deal although they did stay on the same reef system and were smaller ($\bar{x}=159$ mm SL). When Larson removed territory holders (*S. chrysomelas*) from the reef, shelter holes were quickly colonized by territory holders (looking for better habitat?), floaters, and commuters (*S. carnatus*). The fact that territory holders moved in to colonize vacated habitat suggests that there is some sort of hierarchy in the quality of habitat. Thus, it appears that territory holders are willing to give up their established territories if more desirable habitat becomes available.

The rockfishes that moved from the natural reefs to the artificial reef in this study could have been commuters, floaters, or strictly territorial as I had not examined their behavior before the installation of the artificial reef. Regardless of the particular type of behavior exhibited by these fishes, they must be roaming about more than previous studies have reported. The fact that adult fishes were leaving natural reefs to roam about suggests that these reefs were overpopulated or sub-optimal in some way. The natural reefs may have been limiting in regard to the number of suitable shelter holes available in comparison to the number of *S. carnatus* and *S. chrysomelas* present. It is also possible that some of the rockfishes inhabiting these natural reefs had sub-optimal territories. The natural reefs had less vertical relief and spatial heterogeneity than the artificial reef. Larson (1980*c*) reported that reefs could support denser numbers of black-and-yellow and gopher rockfishes when the rock bottom was more complex and had more shelter holes.

The existence of few large predatory fishes in temperate reef systems, as opposed to tropical systems, may result in increased mobility, especially at night when some rockfishes are more active (Ebeling and Bray 1976). Fishes may be mobile in temperate systems resulting in quick recruitment onto artificial reefs or areas cleared of adult fishes. Perhaps due to this difference in predation pressure, in tropical systems most of the fish recuitment on artificial reefs is from juvenile settlement from the plankton (Talbot et al. 1978) as opposed to temperate recruitment which is largely by adult and subadult fishes (Gascon and Miller 1981, Matthews 1985, Solonsky 1985). Similarly, Cross (1981) found adult recruitment of tidepool fishes in areas cleared in Washington; the tidepool colonizers having traveled over sandy areas where predation would be expected to be high in tropical systems. The rockfishes moving from the natural reefs in my

study also had to travel over sandy areas to reach the artificial reef. Thus, reduced predation pressure may result in more mobility in fishes of temperate reefs.

Fishes may be more mobile in low relief areas thereby accounting for the lack of movement reported in benthic rockfishes (studies usually being conducted on high relief reefs). In an associated study Solonsky (1985) found fishes that colonized the artificial reef to be very sedentary with no movement from the artificial reef back to the natural reefs being observed. This would suggest that the quality of habitat offered by the artificial reef (shelter, food?) was high, with fishes being less likely to move away. Also, we found black-and-yellow and gopher rockfishes to be more prone to capture by sportfishing than other reef residents, with these two species being caught in higher proportions by our hook-and-line fishing than would be expected from their numbers on our underwater transects (Matthews 1985, Solonsky 1985). On the natural reefs, black-and-yellow rockfish comprised 6% and gopher rockfish 18% of the 272 fishes caught by hook-and-line, while the two species together made up only 2% of the 4319 fishes observed underwater. Perhaps some aspect of their territorial and aggressive behavior makes them more prone to fishing pressure.

Evidently there is much to be learned about movement in temperate fishes and this aspect should be investigated to aid in reef fish management. Movement by black-and-yellow and gopher rockfishes to higher relief artificial and natural reefs, high vulnerability of these relatively nonabundant territorial fishes to sportfishing, combined with the substantial fishing pressure artificial and high relief natural reefs receive, could subject these species to overfishing. These factors need to be considered for effective management of nearshore territorial rockfishes.

ACKNOWLEDGMENTS

My thanks is extended to G. Cailliet, M. Foster, and R. Larson and everyone at Moss Landing Marine Laboratories, where this research was conducted. A Packard Foundation research grant was very helpful in buying supplies for the project as well as providing funds for the tag return lottery. F. Henry, R. N. Lea, and J. Hardwick of the California Department of Fish and Game provided assistance and advice on the artificial reef logistics. Finally, this paper was presented at the 1985 Western Groundfish Conference and my attendance was funded by the University of Washington School of Fisheries.

LITERATURE CITED

Cross, J. C. 1981. Structure of a rocky intertidal fish assemblage. Dissertation. University of Washington, Seattle.

Ebeling, A. W., and R. N. Bray. 1976. Day versus night activities of reef fishes in a kelp forest off Santa Barbara, California. Fish. Bull., 74:703–717.

Gascon, D., and R. A. Miller. 1981. Colonization by nearshore fish small artificial reefs in Barkeley Sound, British Columbia. Can. J. Zool., 59:1633–1646.

Hallacher, L. E. 1977. Patterns of space and food use by inshore rockfishes (Scorpaenidae:*Sebastes*) of Carmel Bay, California. Dissertation. University of California, Berkeley.

——— 1984. Relocation of original territories by displaced black-and-yellow rockfish, *Sebastes chrysomelas,* from Carmel Bay, California. Calif. Fish Game, 7(3):158–162.

Hixon, M. A. 1981. An experimental analysis of territoriality in the California reef fish *Embiotoca jacksoni* (Embiotocidae). Copeia, 1981(3):653–665.

Larson, R. J. 1980*a*. Territorial behavior of the black-and-yellow and gopher rockfish (Scorpaenidae, *Sebastes*). Mar. Biol., 58.111–122.

——— 1980*b*. Influence of territoriality on adult density two rockfishes of the genus *Sebastes*. Mar. Biol., 58:123–132.

———. 1980*c*. Competition, habitat selection, and the bathymetric segregation of two rockfish (*Sebastes*) species. Ecol. Monogr., 50(2):221–239.

Lea, R. N. 1983. Current approaches to and problems with rockfish systematics. Abstract in: F. Henry editor. Proceedings of the 1983 Groundfish Workshop. Monterey, California.

Love, M. S. 1978. Aspects of the life history of the olive rockfish *Sebastes serranoides*. Disseration. University of California at Santa Barbara.

———. 1983. Movements of rockfishes. Abstract in F. Henry editor. Proceedings of the 1983 Groundfish Workshop. Monterey, California.

Matthews, K. R. 1985. Species similarity and movement of fishes on natural and artificial reefs in Monterey Bay, California. Bull.Mar. Sci., 37(1):252–270.

Miller, D. J., and J. J. Geibel. 1973. Summary of blue rockfish and lingcod life histories; A reef ecology study; and giant kelp *Macrocystis pyrifera*, experiments in Monterey Bay, California. Cali. Dept. of Fish and Game Fish. Bull. (158) 137p.

Miller, D. J., and R. N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dept. Fish Game. Bull. (157) 235p.

Moulton, L. L. 1977. An ecological analysis of fishes inhabiting the rocky nearshore regions of northern Pudget Sound, Washington. Dissertation. University of Washington, Seattle.

Solonsky, A. C. 1985. Fish colonization and the effect of fishing activities on two artificial reefs in Monterey Bay, California. Bull. Mar. Sci. 37(1):336–347.

Talbot, F. H., B. C. Russell, and G.R.V. Anderson. 1978. Coral reef fish communities: unstable, high diversity systems? Ecol. Monogr., 48(4):425–440.

Walton, J. M. 1979. Puget Sound artificial reef study. Wash. Dept. Fish. Tech. Rep. 50. 130p.

Calif. Fish and Game 72(2): 110–116 1986

RELATING MARTEN SCAT CONTENTS TO PREY CONSUMED [1]

WILLIAM J. ZIELINSKI [2]
Department of Forestry and Resource Management,
University of California, Berkeley, CA 94720.

A European ferret, *Mustela putorius furo,* was fed typical marten food items to discover the relationship between prey weight and number of scats produced per unit weight of prey. A correction factor was derived that was used in the analysis of pine marten, *Martes americana,* scats to produce a method capable of comparing foods on a "percent-by-prey-weight" basis. The results of this analysis are compared to traditional scat analysis methods and found to differ substantially. The differences were greatest when compared to analysis by "frequency-of-occurrence".

INTRODUCTION

Frequency of occurrence has been commonly used to relate carnivore scat contents to prey consumed, but the biases inherent in this method are well documented (Scott 1941, Latham 1951, Lockie 1959, Greenwood 1979, Korschgen 1980). Lockie (1959) and Gosczczynski (1974) tried to rectify this problem in the red fox, *Vulpes vulpes,* by deriving correction factors for converting fractional weights of scat contents to actual weights of prey. This was more accurate, but the authors did not account for the influence of prey size on the number of scats produced. Floyd, Mech, and Jordan (1978), experimenting with captive wolves, *Canis lupus,* discovered a strong negative correlation between the number of scats produced per kilogram of prey and the size of the prey item. This phenomenon was apparently due to the increasing proportion of indigestible material as prey size decreases.

During a study of pine marten ecology (Zielinski 1981, Spencer 1981) it became necessary to determine the seasonal diet. Because martens eat prey of many sizes, it is possible that the number of scats produced per unit weight of food eaten could be influenced by prey size. If the same relationship exists in marten scat production that Floyd et al. (1978) found in their analysis of wolf scats, ignoring it could seriously bias the results. For this reason I fed a captive male ferret (an animal which resembles a marten in size, weight and diet) a variety of typical marten foods to determine the number of scats produced per prey consumed. The feeding trials resulted in a procedure capable of estimating the original weight of prey remains discovered in marten scats. This information permitted the marten diet to be analyzed by "percent-by-prey-weight" which could be compared with traditional scat analysis methods. Work was conducted at the University of California, Sagehen Creek Field Station, Nevada Co., California (1950 m elevation).

METHODS

The feeding trials were run from April throuh July 1979. The animal was housed in a 1.5 x 1.5 x 0.75 m wire mesh cage in a small outbuilding where it was subject to normal photoperiod and temperature fluctuations. Water was provided *ad libitum.*

---

[1] Accepted for publication December 1985
[2] Present address: Zoology Dept., Box 7617, North Carolina State University, Raleigh, NC 27695-7617

Preliminary marten scat analyses and information from the literature were used to identify the principal marten prey items. Seven items were selected based on the diversity of sizes that they represented and their availability (Table 1). Unfortunately, the martens largest prey, the snowshoe hare, *Lepus americana,* was not available. Carcasses of each prey were weighed and offered to the ferret one at a time for 4 d. The orts (prey remains) were weighed daily and replaced until they had been fed upon completely or ignored by the ferret for 2 d. After the fourth day all orts were removed and the scat collection continued for an additional 24 h. The end of the fifth day of one trial usually became the beginning of the first day of the ensuing trial, allowing the ferret a minimum of 24 hours to become post-absorptive. This was probably sufficient because captive martens required no more than 19 h to pass the final scat from a meal (More 1978). Cessation of scat production also indicated a post-absorptive state.

TABLE 1. Pine Marten Prey Fed to Ferret and the Relationship of Prey Weight to Number of Scats Produced.

Prey item	*Mean prey[a] weight (g)*	*Number fed*	*Number scats per 100g prey*	*Grams of prey[b] per scat*
Peromyscus maniculatus	17.02	43	10.26	9.75
	17.70		8.73	11.45
Aves	21.90	26	9.80	10.20
	15.50		10.86	9.21
Microtus spp.	37.90	18[c]	8.97	11.15
	35.97		9.12	10.96
Eutamias spp.	50.40	15	7.24	13.81
	53.27		7.79	12.84
Glaucomys sabrinus	119.35	7	7.08	14.12
	126.70		6.05	15.38
Spermophilus lateralis	117.80	7	7.18	13.93
	140.60		6.49	15.41
Tamiasciurus douglasii	248.95	4	5.64	17.73
	189.80		6.73	14.88

[a] The first and second pair of numbers for each prey item refers to Day 1 plus Day 4 and Day 2 plus Day 3 trials respectively (see text).
[b] The mean weight of prey necessary to produce one scat.
[c] Three day trial.

Scats were collected as frequently as possible throughout the day and night to minimize trampling and to avoid confusion in separating scats deposited in aggregations. Although the first and last scats collected during a trial were less cohesive than those in between, they too were included in the analysis. Scats that resulted from meals fed on days 1 and 4 were analyzed separately from those on days 2 and 3. This was necessary because scat production did not usually begin until late in day 1, whereas scat production continued well after the final carcass was offered on day 4. Therefore, each 4 day trial resulted in two mean values (one for days 1 and 4 and one for days 2 and 3) for prey weight, number of scats per 100 g prey and the weight of prey necessary to produce one scat.

In an earlier study, 300 marten scats were analyzed according to three traditional methods: (i) frequency of occurrence (by number of items), (ii) volumetric percent of contents, and (iii) percent by weight of contents (Zielinski

1981). The present study provided a method of determining the number of scats produced per weight of prey consumed, which in turn were applied to marten scat data to provide a fourth method of analysis: "percent-by-prey-weight". This method was then compared to the traditional methods listed above. The marten scat analysis methods and a complete summary of the results are compiled by Zielinski, Spencer, and Barrett (1983).

RESULTS

The relationship of prey weight to scats produced is presented as number of scats produced per 100 g of prey and also by the weight of undigested prey that a scat represented (Table 1). The number of scats produced per 100 g of prey increased with decreasing prey size. Smaller prey items were eaten completely and produced more scats per unit weight than larger items. Weight of prey represented by each scat increased with increasing prey weight.

A strong positive correlation ($r^2 = 0.89$, $P < .005$) was discovered between number of scats produced by the ferret and the weight of prey consumed (Figure 1). Ultimately, the estimate of total prey weight consumed by martens was determined from the regression equation derived from ferret scat data. For example, the mean weight of 43 deer mice, *Peromyscus maniculatus,* fed to the ferret was 17.6 g ($\ln = 2.85$), and the equation estimates that 9.9 g of prey of this weight will result in one scat. Thus, had 10 marten scats contained deer mouse exclusively, each representing 9.9 g of mouse eaten, then those 10 scats were produced by the consumption of approximately 99 g of mouse. The same value would result if deer mouse remains comprised fractional parts of more than 10 scats, but when totaled equaled 10 scats. Thus, 99 grams and its percent of total original weight of prey comprised the "percent-by-prey-weight" analysis. When the total weight for each prey species is divided by the mean prey weight, the number of individuals eaten can also be calculated (Table 2).

The four analysis techniques were compared using the information from scats collected from early spring to mid-summer, 1979 and 1980 (Figure 2). The histograms illustrate the four methods applied to nine prey items increasing in body size from left to right. This presentation includes only prey whose mean weights fall within the predictive limits of the regression, and is not intended to describe the marten diet but only to provide data for comparisons. Although flying squirrels, *Glaucomys sabrinus,* were not represented in the spring–summer marten scat data, they were included in the feeding trials to make the comparison of analysis techniques more robust.

Assuming "percent-by-prey-weight" is the most accurate interpretation of scat results, the three other techniques overestimate the importance of smaller items and underestimate the importance of larger items in the diet. Frequency of occurrence differed the greatest from percent-by-prey-weight. Occurrence as a percent of total number of items deviated from percent of original prey weight by 33% (when analyzed as percent of total number of scats the deviation was 38%). Percent weight and percent volume of scat differed from percent-by-prey-weight by 21 and 19%, respectively. The four techniques were most similar for prey of intermediate weight.

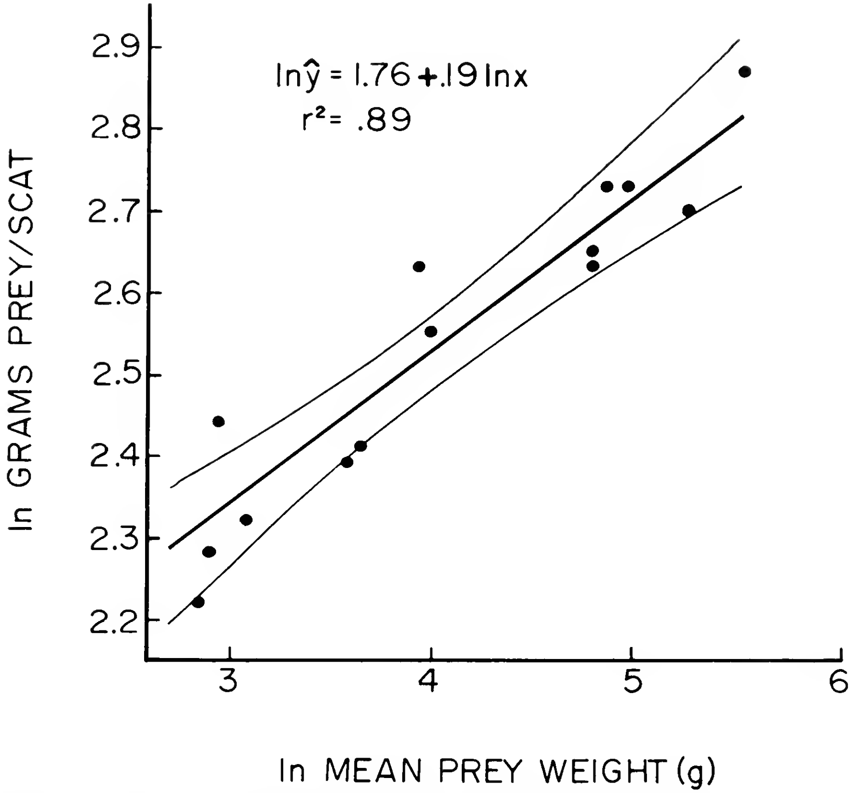

FIGURE 1. Relationship between prey weight and grams of prey required to produce one scat.

TABLE 2. Original Weights and Number of Individual Prey Represented by the Contents of Pine Marten Scats Deposited Between 25 April and 2 July 1979, 1980.

Prey item	*Mean wt.* [a] *(g)*	*Grams* [b] *prey/scat*	*Number* [c] *scats*	*Wt. of prey* [d] *eaten*	*Number* [e] *indiv. prey*
Sorex spp.	7.10	8.50	3.3	28.1	3.9
Peromyscus maniculatus	17.36	10.07	1.0	10.1	0.6
Aves	18.70	10.18	5.0	50.9	2.7
Microtus spp.	36.90	11.63	20.0	232.6	6.3
Eutamias spp.	51.83	12.43	6.2	77.1	1.5
Scapanus latimanus	68.70	13.07	3.1	40.5	0.6
Thomomys monticola	96.40	14.01	1.1	15.4	0.2
Spermophilus lateralis	129.20	14.73	10.6	156.1	1.2
Tamiasciurus douglasii	219.35	16.44	3.1	51.0	0.2
TOTALS			53.4	661.8	

[a] Average of carcasses fed during feeding trials or taken from museum specimens in Sagehen Creek field station collection.
[b] From ferret feeding trials.
[c] Composite number of marten scats which contained the item.
[d] Grams prey per scat multiplied by number of scats.
[e] Weight of prey eaten divided by mean prey weight.

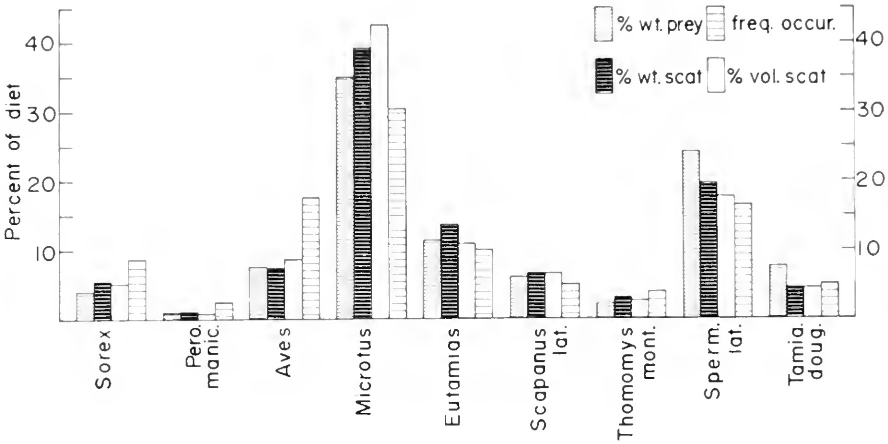

FIGURE 2. Comparison of four scat analysis techniques applied to selected prey discovered in marten scats deposited from 25 April–2 July 1979 and 1980.

Food items changed importance rankings when analyzed by different techniques (Table 3). Only three items changed ranked position when volume and weight are compared to percent-by-prey-weight. However, when frequency of occurrence is compared to percent-by-prey-weight, five items are ranked differently.

TABLE 3. Rank Order of Importance of Marten Prey as Determined by Different Analyses.

Prey	*Prey weight*	*Frequency of occurrence*	*Volume*	*Weight*
Microtus	1	1	1	1
S. lateralis	2	3	2	2
Eutamias	3	4	3	3
Aves	4	2	4	4
Tamiasciurus	5	7	7	7
Scapanus	6	6	5	5
Sorex	7	5	6	6
Thomomys	8	8	8	8
Peromyscus	9	9	9	9

DISCUSSION

Traditional scat analysis methods overestimated the importance of small prey and underestimated the importance of large prey. Two factors contributed to this result. The most significant influence was the fact that small prey have a higher ratio of undigestible to digestible matter in their bodies. Because the ratio of surface area to volume increases with decreasing body size (Kleiber 1947), the ratio of hair and feathers ingested per unit volume of body increases also. Johnson and Hansen (1979) found that the hair and skeleton of deer mice averaged 77.0% of dry weight, whereas 22.0% of the body weight of black-tailed jackrabbits, *Lepus californicus,* was recovered in scats. Secondly, small prey were entirely consumed whereas some hair, skin and the larger bones of large prey were often uneaten. Because less undigestible matter was consumed,

the larger prey produced fewer scats per 100 grams of their weight. This relationship would probably have been strengthened had very large prey, such as the snowshoe hare, been included in the feeding trials.

The variation among techniques was greatest at prey size extremes. Frequency of occurrence was a poor estimate of the undigested weight of small and large prey but approximated the weight of intermediate sized prey. This may be related to the size and similarity of prey at these weights. King (1980) found that when the weasel, *Mustela nivalis,* consumed prey larger than its stomach capacity, its stomach and scats rarely contained more than one prey type. For this reason, the usual disadvantages of frequency of occurrence analysis did not apply. The same exemption may hold true when martens or ferrets consume intermediate sized prey. Because *Eutamias* spp., *Thomomys monticola,* and *Scapanus latimanus* are of similar size and each probably exceeds the marten's stomach capacity, analysis by frequency of occurrence was a satisfactory estimate of their undigested weight. Frequency of occurence was also a reasonably close estimate of original vole, *Microtus* spp., weight despite their small size. Unlike other small mammals, vole remains were easily identified and regularly comprised the entire volume of the marten scat in which they were discovered. Because martens frequently hunt along meadow edges (Spencer 1981) where voles are common, several individuals may be eaten in succession, resulting in a homogenous series of scats comprised entirely of vole remains. This situation would result in a low ratio of frequency to volume much like that described for the intermediate sized prey above.

The unusually high frequency of occurrence of birds when compared to other methods is probably an artifact of the visibility of their remains and the amount of undigestible matter in their bodies. Were a mammal to be represented by only a few hairs, these would be much easier to overlook than feathers. Birds also contain a larger percent of undigestible matter than mammals of equal size (Johnson and Hansen 1979). Due to these characteristics, the avian component of the diet was extremely overestimated, appearing to exceed both *Eutamias* and *Tamiasciurus* when analyzed by frequency of occurrence. However, birds were ranked less than or equal to these mammals when analyzed by percent-by-prey-weight.

Lockie (1959) developed correction factors that he used to estimate the original weight of red fox (adult and cub) prey when multiplied by the weight of the remains in scats. He suggested that the correction factors for fox cubs might be suitable for martens as well. Although he came about the information differently, our procedures each resulted in an estimate of the original weight of prey and can therefore be compared. The only prey category for which a comparison is relevant however, is *Microtus,* since Lockie did not provide fox cub correction factors for any other mammalian category. Applying his correction factor to weights of marten scats containing vole remains resulted in an original weight estimate of 671.0 g. This was about three times the original weight estimate presented in the present analysis. Although this is by no means a critical test of his assumption, it does suggest that the fox cub scat correction factors may overestimate the original prey weights when applied to marten or ferret scat data.

Admittedly, inferences about marten feeding and digestion based on a captive ferret are tenuous. The ferret seemed less active than wild martens and activity may influence scat production. However, Davison (1975) and Powell (1979)

both stated that free-living fishers, *Martes pennanti,* were less active than captive ones. Although activity may accelerate the movement of food through the digestive tract, the rate of food passage is not important provided the digestibility is not affected. Documentation of this relationship is lacking, however.

In summary, although all traditional techniques were found to overestimate the importance of small prey and underestimate large prey, volumetric estimates of prey remains came closest to estimating the weight of the prey included in the trials. For this reason, and because relative volume of scat contents is easier to estimate visually than relative weight, volumetric measures are recommended for the analysis of marten scat contents.

ACKNOWLEDGMENTS

Funding was provided by Region 5 of the U.S. Forest Service and by McIntyer-Stennis project 3501 of the California Agricultural Experiment Station. I express my gratitude to D. Jessup of the California Department of Fish and Game for his help in procuring the ferret. Many thanks to W. Spencer for help in the field and R. Barrett, W. Lidicker and R. Powell for their comments on the manuscript.

LITERATURE CITED

Davison, R. P. 1975. The efficiency of food utilization and energy requirements of captive fishers. Unpubl. thesis, Univ. New Hampshire, Concor. 53 pp.

Floyd, T. J., L. D. Mech, and P. A. Jordan. 1978. Relating wolf scat content to prey consumed. J. Wildl. Manage., 42:528–532.

Gosczczynski, J. 1974. Studies on the food of foxes. Acta. Theriol., 19:1–18.

Greenwood, R. J. 1979. Relating residue in raccoon feces to food consumed. Amer. Midl. Nat., 102:191–193.

Johnson, M. K., and R. M. Hansen. 1979. Estimating coyote food intake from undigested residues in scats. Amer. Midl. Nat., 102:363–367.

King, C. M. 1980. The weasel, (*Mustela nivalis*), and its prey in an English woodland. J. Anim. Ecol., 49:127–159.

Kleiber, M. 1947. Body size and metabolic rate. Physiol. Rev., 27:511–541.

Korschgen, L. J. 1980. Procedures for food-habits analyses. Pages 113–127, *in* S. Schemnitz ed., Wildlife Management Techniques Manual. The Wildlife Society, Washington, D.C.

Latham, R. M. 1951. The ecology and economics of predator management. Penn. Game Comm. Rep. II, Harrisburg, 96 pp.

Lockie, J. D. 1959. Estimation of the food of foxes. J. Wildl. Manage., 23:224–227.

More, G. 1978. Ecological aspects of food selection in pine marten. Unpub. thesis, Univ. Alberta. 94 pp.

Powell, R. A. 1979. Ecological energetics and foraging strategies of the fisher (*Martes pennanti*). J. Anim. Ecol., 48:195–212.

Scott, T. G. 1941. Methods and computations in fecal analysis with reference to the red fox. Iowa State Coll. J. Sci., 15:279–285.

Spencer, W. D. 1981. Pine marten habitat preferences at Sagehen Creek, California. Unpubl. thesis, Univ. California, Berkeley. 121 pp.

Zielinski, W. J. 1981. Food habits, activity patterns and ectoparasites of the pine marten at Sagehen Creek, California. Unpubl. thesis, Univ. California, Berkeley, 121 pp.

Zielinski, W. J., W. D. Spencer, and R. H. Barrett. 1983. Relationship between food habits and activity patterns of pine martens. J. Mammal., 64:387–396.

Calif. Fish and Game 72(2): 117–126 1986

NOTES

FIRST RECORD OF *HEMITRIPTERUS BOLINI*, THE BIGMOUTH SCULPIN, FROM CALIFORNIAN WATERS.

On 30 April 1985, while trawling off Eureka for Dover sole, *Microstomus pacificus,* the crew of the CHEROKEE landed amongst their catch a large fish with which they were unfamiliar. The specimen, a gravid female, 73.0 cm total length (TL) and 8.5 kg when fresh, proved to be *Hemitripterus bolini* (Myers, 1934), the bigmouth sculpin (Figure 1). The species was previously not known from Californian waters. The sculpin was taken by bottom trawl fished at 130 fm (238 m) at lat 40° 43.4′–43.6′ N, long 124° 28.4′–30.3′ W. The capture of this sculpin brings to 45 the number of cottids known from California marine waters. The distribution of this boreal species has been given as Bering Sea to northern British Columbia (Hart 1973). Previous maximum size, given also by Hart (1973), was "Length to 27 inches (69 cm)," 4 cm less than the California specimen.

FIGURE 1. Plate of *Ulca marmorata* [=*Hemitripterus bolini*] from Jordan 1896. Size of specimen ca. 130 mm TL.

Hemitripterus bolini has had a somewhat complex nomenclatural history; a synonomy follows:

Hemitripterus marmoratus Bean, 1890.
(type-locality: off Sitkalidak Island, Alaska. ALBATROSS sta. 2855).

Ulca marmorata (Bean, 1890).
(new genus: *Ulca* Jordan & Evermann *in* Jordan 1896).

Ulca bolini Myers, 1934.
(replacement name: *H. marmoratus* Bean, 1890 a homonym of *H. marmoratus* Ayres, 1854, = *Scorpaenichthys marmoratus* (Ayres)).

Hemitripterus bolini (Myers, 1934).
(principal usage since Clemens and Wilby 1961).

The Californian specimen fits well the descriptions given by Bean (1890; brief), Gilbert (1895), Jordan and Evermann (1898), Clemens and Wilby (1961), and Hart (1973). Counts and morphometrics for the Californian specimen are given in Table 1. Additionally, the liver was noted as 'bright orange.' The ovaries, which filled a large portion of the abdominal cavity, weighed 2155 g. Two items were removed from the stomach: a highly digested fish of the genus *Sebastes,* ca.220 mm standard length (SL), and the whelk, *Neptunea pribiloffensis,* 115 mm × 57 mm.

The specimen is deposited in the Department of Ichthyology, California Academy of Sciences; CAS 57348.

TABLE 1. Counts and Morphometrics of Californian Specimen of *Hemitripterus bolini*

Counts:		
Dorsal fin	XIV + 12	
Anal fin	13	
Pectoral fin	L 21, R 22	
Pelvic fin	I, 3	
Gill rakers (L)	5 + 16; all spinulate	
Lateral line pores	41 + 1	
Pyloric caeca	8; elongate	
Morphometrics: [1]		
measurement	*mm*	*percent SL*
Standard length	560	—
Total length	690	123
Head length	216.2	39
Snout	52.5	09
Orbit width	44.4	08
Interorbital width	73.0	13
Maxilla	132.0	24
Width of head	241.7	43
Width of body	210.0	38
Pectoral length	155.0	28
Pelvic length	70.6	13
Longest dorsal spine [2]	48.6	09
Longest dorsal ray	88.0	16
Longest anal ray	69.8	12
Dorsal 1 base	170.0	30
Dorsal 2 base	140.0	25
Distance between D1 and D2	39.2	07
Anal base	145.7	26
Anus to anal fin	104.0	19
Length of caudal peduncle (dorsal)	88.1	16
Length of caudal peduncle (ventral)	72.3	13
Depth of caudal peduncle	45.0	08
Length of gill raker at angle	4.3	01
Length of gill lamellae at angle	28.1	05
Caudal length	119.9	21

[1] Measurements taken after specimen frozen and thawed.
[2] Length of spine only, not including pennant.

ACKNOWLEDGMENTS

We would like to thank D. Crowley and the crew of the CHEROKEE for their cooperation in saving unusual fishes in the interest of science. J. Cotany, of the Meredith Fish Company, contacted us about the specimen and has continually

encouraged fishermen to save uncommon fishes for our examination. The staff of the Department of Ichthyology, California Academy of Sciences, provided comparative material. This research was supported in part by Federal Aid in Fish Restoration Act funds to California Dingell-Johnson F-25-R, Central California Marine Sportfish Survey.

LITERATURE CITED

Bean, T. H. 1890. Scientific results of explorations by the U.S. Fish Commission Steamer ALBATROSS. No. XI.—New fishes collected off the coast of Alaska and the adjacent region southward. Proc. U.S. Nat. Mus., 13 (795): 37–45.

Clemens, W. A., and G. V. Wilby. 1961. Fishes of the Pacific coast of Canada. 2nd ed. Bull. Fish Res. Bd. Canada, No. 68:1–443.

Gilbert, C. H. 1895. The ichthyological collections of the steamer ALBATROSS during the years 1890 and 1891. Rept. U.S. Comm. Fish and Fisheries, 19: 393–476.

Hart, J. L. 1973. Pacific fishes of Canada. Bull. Fish. Res. Bd. Canada, 180: 1–740.

Jordan, D. S. 1896. Notes on fishes, little known or new to science. Proc. Cal. Acad. Sci., 2nd ser., 6: 201–244.

Jordan, D. S., and B. W. Evermann. 1898. The fishes of North and Middle America. Bull. U.S. Nat. Mus., No. 47, Pt. 2: 1241–2183.

Myers, G. S. 1934. A new name for the Alaskan cottoid fish *Ulca marmorata* (Bean). Copeia, 1934(1): 44.

—Robert N. Lea, California Department of Fish and Game, Marine Resources Branch, 2201 Garden Road, Monterey, California 93940 and Lawrence F. Quirollo, California Department of Fish and Game, Marine Resources Region, 619 Second Street, Eureka, California 95501. *Accepted for publication September 1985.*

NORTHERN RANGE EXTENSION FOR CALIFORNIA TONGUEFISH, *SYMPHURUS ATRICAUDA*, TO WASHINGTON STATE

Seven specimens of the California tonguefish, *Symphurus atricauda*—Family Cynoglossidae, were collected from Washington marine waters during beam trawl (3.0 m) sampling for Dungeness crab, *Cancer magister.* Six tonguefish were recovered from the Grays Harbor estuary of southwest Washington during the summer of 1983 and one specimen from Samish Bay, north Puget Sound, in December 1984 (Table 1).

Until recent years the California tonguefish was reported to range from Baja California to Monterey Bay, California (Roedel 1953). In the last two decades several northern range extensions have been noted for this species including Humboldt County, California (Miller, Gotshall, and Nitsos 1965) and Yaquina Bay, Oregon (Krygier, Johnson, and Bond 1973). The occurrence of tonguefish in Washington waters extends the known range of this species by 425 latitudinal km. It is of interest that the Samish Bay specimen was caught a substantial distance into Puget Sound, 160 km east of Cape Flattery.

Krygier et al. (1973) considered "The presence of a few members of an apparently single year class in Yaquina Bay, 240 miles north of Big Lagoon (Humboldt County, Calif.) may be due to successful drift of larvae in the northerly directed Davidson Current." It is this condition that probably accounts for periodic sightings of "Californian" species in Oregon and Washington waters.

TABLE 1. Catch Data for California Tonguefish Collected from Washington Waters During 1983 and 1984.

Catch location	*Latitude*	*Longitude*	*Date collected*	*Depth of capture (m)*	*Bottom temperature (°C)*	*Salinity (‰)*	*Weight (g)*	*Total length (mm)*
Grays Harbor Estuary	46°57′53″N	124°06′18″W	7/24/83	6	11.7	33	0.9	NM
Grays Harbor Estuary	46°59′40″N	124°03′82″W	7/26/83	4	16.0	23	NM	NM
Grays Harbor Estuary	46°55′98″N	123°56′35″W	8/09/83	4	NM	NM	2.7	NM
Grays Harbor Estuary	46°55′62″N	123°59′20″W	8/23/83	8	16.8	26	2.7	NM
Grays Harbor Estuary	46°58′52″N	124°03′20″W	8/24/83	4	16.0	28	2.3	NM
Offshore Grays Harbor	46°54′53″N	124°14′25″W	9/13/83	29	NM	NM	5.1	81
Samish Bay, Puget Sound	48°35′05″N	122°32′45″W	12/02/84	NM	NM	NM	NM	87 *

* University of Washington, School of Fisheries Fish Collection #UW21143
NM = Not measured

Tonguefish were observed in Yaquina Bay, Oregon in March, April, and May of 1983 (cited in Fluharty 1984), caught in Grays Harbor, Washington in July, August, and September of 1983 and also from Samish Bay in December 1984 (Table 1). This pattern of occurrences strongly suggests that planktonic eggs or larvae of tonguefish were carried as far north as Puget Sound by the Davidson Current. Indeed, Fluharty (1984) records five other northern range extensions for fishes during 1982–83 as well as the rare occurrence of 13 additional "southern" fish species.

ACKNOWLEDGMENTS

The authors are indebted to the following for their help with tonguefish captures and manuscript preparation: D. Armstrong, D. Baumgarner, K. Carrasco, C. Dungan, C. Eaton, D. Fluharty, G. Jensen, and A. Mearns. The crab studies responsible for the capture of California tonguefish were funded in part by the University of Washington Sea Grant Program with funds from the National Oceanographic and Atmospheric Administration and the University of Washington.

LITERATURE CITED

Fluharty, D. 1984 1982–1983 El Nino Summary. Institute of Marine Studies, HF-05, University of Washington, Seattle. 25 p

Krygier, E.E., W.C. Johnson, and C.E. Bond. 1973. Records of California Tonguefish, Threadfin Shad and Smooth Alligatorfish from Yaquina Bay, Oregon. Calif. Fish Game, 59(2):140–142.

Miller, D.J., D. Gotshall, and R. Nitsos. 1965. A Field Guide to Some Common Ocean Sport Fishes of California (Second revision). Calif. Depart. Fish and Game, Sacramento. 87 p.

Roedel, P.M. 1953. Common Ocean Fishes of the California Coast. Calif. Fish and Game, Fish Bull.(91) 184 p.

—Paul A. Dinnel and Christopher W. Rogers, School of Fisheries, University of Washington, Seattle, Washington 98195. *Accepted for publication April 1985.*

INDIGENOUS MUSKRATS, *ONDATRA ZIBETHICUS*, IN COASTAL SOUTHERN CALIFORNIA

The origin and distribution of muskrats in California is reported in detail by Storer (1938), Twining and Hensley (1943) and Seymour (1954). The only populations considered indigenous within California are *Ondatra zibethicus mergens* in northeastern California and *O. z. bernardi* along the Colorado River (Hall and Cockrum 1953, Hall and Kelson 1959). Populations in other portions of the state are considered to be recent introductions, primarily by trappers seeking to augment their harvests.

Recent excavations at a paleontological site and two archaeological sites within the Santa Ana River drainage indicate that muskrats were indigenous from the Late Pleistocene onward. The first evidence of muskrat in the region was the discovery of a right femur (LACM 18973) at Costeau Pit (LACM Loc. V65129), 18 km east of Newport Bay (Miller 1971). This specimen is part of a Rancholabrean vertebrate assemblage recovered from a sandy silt of lacustrine or plaustrine origin (Miller 1971). The assemblage was deposited during the middle of the Rancholabrean Age. The single radiocarbon date for the site indicates an age in excess of 40,000 years before present (B.P.) (Miller 1971).

Two specimens were recovered from archaeological site Ca-Ora-119A located near the San Joaquin Marsh in Upper Newport Bay (P. Langenwalter, unpubl. data). Ora-119A contains assemblages from three culture periods. A left as-

tragalus (Ora-119A:40N/40E:50–60) was recovered from the oldest assemblage, deposited during the Milling Stone Horizon (Wallace 1955). Radiocarbon dates from this portion of the site indicate deposition between circa (ca.) 6190 and 2925 years B.P. (H. Koerper, unpubl. diss.).

A left dentary (Ora-119A:CC3:30–40) was recovered from the middle assemblage belonging to the Intermediate Horizon. Dates for this assemblage indicate deposition between ca. 2035 and 1550 years B.P. (H. Koerper, unpubl. diss.).

Archaeological site Ca-Ora-193, also located in Upper Newport Bay, yielded three specimens (Langenwalter 1981). These specimens include a left dentary (45-875), a left maxilla (45-I9:80–100) and a left tibia (45-E11:20–40). The Ora-193 assemblage was deposited during the Late Horizon. The upper portion of the midden, which yielded the specimens, was deposited between ca. 1430 and 750 years B.P. based on radiocarbon dates (Lyneis 1981). The muskrat remains were recovered from the uppermost strata and were probably deposited through natural agency not associated with the aboriginal occupation.

Thompson (unpubl. thesis) reported the modern presence of muskrats in the San Joaquin Marsh, which is located in Upper Newport Bay. Additional sightings have been made in marshy areas around edges of the bay. It has not been determined if this population is a vestige of the pre-historic population or if it is a recently introduced subspecies.

The specimens mentioned above are housed in several institutions including the Natural History Museum of Los Angeles County (LACM Loc. 65129); Archaeological Resource Management Corporation, Garden Grove (Ora-119A); and California State University, Long Beach (Ora-193).

LITERATURE CITED

Hall, E. R., and E. L. Cockrum. 1953. A synopsis of North American microtine rodents. Univ. Kansas Publ., Mus. Nat. Hist. 5:373–498.

Hall, E. R., and E. L. Kelson. 1959. The mammals of North America. The Ronald Press Co., New York, 2:547–1083 + 79.

Langenwalter, P. E. 1981. The reptiles and mammals from Ora-193. Pacific Coast Arch. Soc., Quart., 17(2/3):100–118.

Lyneis, M. M. 1981. Excavations at Ora-193, Newport Bay, California. Pacific Coast Arch. Soc., Quart. 17 (2/3):1–80.

Miller, W. E. 1971. Pleistocene vertebrates of the Los Angeles Basin and vicinity (exclusive of Rancho La Brea). Bull. Los Angeles Co. Mus. Nat. Hist. 10.

Seymour, G. D. 1954. Recent extension of the range of muskrats in California. Calif. Fish Game, 40(4):375–384.

Storer, T. I. 1938. The muskrat as native and alien: a chapter in the history of animal acclimitization. Calif. Fish Game, 24(2):159–175.

Twining, H. and A. L. Hensley. 1943. The distribution of muskrats in California. Calif. Fish Game, 29(2):64–78.

Wallace, W. J. 1955. A suggested chronology for southern California coastal archaeology. S.W.J. Anthro., 11(3):214–230.

—Paul E. Langenwalter II. Section of Archaeology, Natural History Museum of Los Angeles County, 900 Exposition Boulevard, Los Angeles, California 90007. *Accepted for publication September 1985.*

MORTALITY OF AMERICAN WIGEON ON A GOLF COURSE TREATED WITH THE ORGANOPHOSPHATE, DIAZINON

Approximately 30 American wigeon, *Anas americana,* died on or about 16 December 1983 in the vicinity of a lake associated with a golf course. They were taken to a local veterinarian, who in turn took them to a California Department

of Food and Agriculture veterinarian. The State veterinarian suggested a diagnosis of toxemia, but no specific cause of death was determined. Two dead wigeon were forwarded to the Wildlife Investigations Laboratory of the Department of Fish and Game (DFG) for further study. We initially suspected Dasanit (fensulfothion) or Diazinon as toxic agents or possibly botulism as an infectious agent, since these had been identified as the cause of death in previous, similar episodes. Diazinon (Ciba-Geigy 500AG) was reported in this case to have been applied at 0.05 kg/100m^2 on 17 November 1983, one month before the death of the ducks.

Samples were analyzed for the suspected pesticides. Liver, gizzard contents, soil, and grass were examined for pesticide residue. Samples were dried and macerated with anhydrous granular sodium sulfate. The dried sample was blended with methylene chloride, vacuum filtered and concentrated to near dryness. Petroleum ether was added and the methylene chlorine was evaporated. The petroleum ether extract was concentrated to a suitable volume. The extract was analyzed with a gas chromatograph equipped with a nitrogen specific detector.

Chemical analyses for Diazinon were positive in all samples. Both the Dasanit and the mouse protection botulism test (Quortrup and Sudenheimer 1943) were negative. Liver tissue ($n=2$) contained approximately 0.14 ppm Diazinon. Gizzard contents of vegetation (grass) and grit, suspended in isopropyl alcohol, contained 2.7 ppm Diazinon. Grass samples taken on 26 January 1984 from the fringe of a "green" contained approximately 3.2 ppm Diazinon. Soil from the root zone contained 1.3 ppm Diazinon. Diazinon toxicosis was therefore indicated as the cause of death. No cholinesterase analyses were made for verification.

Diazinon is toxic to waterfowl with an LD50 of 3.54 mg/kg to young mallards, *Anas platyrhynchos.* Toxicity levels of some other commonly used organophosphates in California are 0.75 mg/kg for Dasanit, 2.4 mg/kg for parathion, and 1485 mg/kg for malathion (Hudson, Tucker and Haegele 1984).

DFG records indicate 800 wigeon were killed by Diazinon at Seal Beach, California in 1972. Toxic levels of Diazinon were detected in gizzard contents and turf (DFG, unpublished report 1972). Canada geese, *Branta canadensis* were killed by Diazinon in Missouri in 1975 (Zinkl, Rather and Hudson 1978). These birds exhibited depressed brain cholinesterase activity. A grass sample from the mouth of a bird was found to have high Diazinon levels although Diazinon had been applied approximately three months prior to the loss. Another incident occurred in 1976 at a Los Alamitos, California, golf course when approximately 100 wigeon and coots, *Fulica americana,* were killed due to an application of Diazinon. Diazinon had been applied one month prior to the mortality (DFG, unpublished report 1976). Finally, the New York Department of Environmental Conservation has also documented losses of birds due to Diazinon and other materials. Cases similar to the ones reported here are referenced in three of their papers (Stone 1979, Stone and Knoch 1982, Stone and Gradoni 1985). The latter reference describes a total of 54 incidents nationwide where Diazinon may have been involved.

A hazard to grazing waterfowl (wigeon, coots, and geese) may be created when Diazinon is applied to golf courses to control turf insects. A lethal condition may exist on the turf from one to three months after application. The "greens" areas of golf courses near water hazards are probably the most attractive to waterfowl and also most hazardous. The fringe of the green where the grass is one to two inches high to especially dangerous.

The writer wishes to acknowledge the assistance of E. Layaye, Deputy Agricultural Commissioner, San Bernardino County for his help in this investigation. Chemical analyses were performed by T. Lew, Chemist, Fish and Wildlife Water Pollution Control Laboratory, DFG.

LITERATURE CITED

Hudson, R. H., R. K. Tucker, and M. A. Haegele. 1984. Handbook of Toxicity of Pesticides to Wildlife. United States Department of Interior, Fish and Wildlife Service. Resource Publication 153. Washington, D.C.

Quortrup, E. R., and R. L. Sudenheimer. 1943. Detection of botulinus toxin in the bloodstream of wild ducks. J. Am. Vet. Med. Assoc., 102:264.

Stone, W. B. 1979. Poisoning of wild birds by organophosphate and carbamate pesticides. N. Y. Fish and Game J., 26(1):37–47.

Stone, W. B., and P. B. Gradoni. 1985. Wildlife mortality related to the use of the pesticide diazinon. Wildlife Resources Center, N. Y. Department Environmental Conservation, Delmar, N.Y.

Stone, W. B., and H. Knoch. 1982. American brant killed on golf courses by diazinon. N. Y. Fish and Game J., 29(1):95–96.

Zinkl, J. G., J. Rather, and R. R. Hudson. 1978. Diazinon poisoning in wild Canada geese. J. Wildl. Manage., 42(2):406–408.

—E. E. Littrell, California Department of Fish and Game, Environmental Services Branch, Pesticide Investigations Unit, 1701 Nimbus Rd., Suite F, Rancho Cordova, CA 95670. *Accepted for publication October 1985.*

THE OCCURRENCE OF *LEPAS ANATIFERA* ON *ZALOPHUS CALIFORNIANUS* AND *MIROUNGA ANGUSTIROSTRIS.*

Lepas anatifera Linnaeus, 1758 is a cosmopolitan species which attaches to drifting or slowly moving objects in the open sea (Pilsbry 1907, Cornwall 1955, Zullo 1979). This barnacle has not previously been reported to occur on pinnipeds.

The California Marine Mammal Center, Fort Cronkhite, California, rescues and rehabilitates sick or injured marine mammals from the central and northern California coastline. From August 1982 to April 1984 nine pinnipeds were admitted with *L. anatifera* attached to their hair and skin. The barnacles were sparsely distributed over the sagittal area of the heads and the dorsal regions of the trunks of eight yearling northern elephant seals, *Mirounga angustirostris*, and one juvenile California sea lion, *Zalophus californianus*, with denser aggregations on the hind flippers (Figure 1). Each pinniped was lethargic and underweight. Seven of the eight *M. angustirostris* had a skin infection, referred to as skin disease or scabby molt (Dierauf 1983).

Barnacle specimens were preserved and deposited at the California Academy of Sciences for identification and measurement (CASIZ Catalog nos. 044144 and 044145). *L. anatifera* from the *M. angustirostris* had carina lengths of 9.2–9.3 mm and total lengths (tip of terga to umbo of scuta) of 12.0–12.75 mm. This suggests an age of 2–3 weeks (Evans 1958). The specimens from the *Z. californianus* were 3.5–5.1 mm in carina length and 4.2–6.1 mm in total length. *L. anatifera* this size would be 1–2 weeks old.

Barnacle ageing has been used to determine growth rates in *Nautilus pompilius* (Landman 1983). By ageing barnacles adhering to sick pinnipeds a veterinarian may estimate minimally the length of time these marine mammals have been drifting or slowly moving. This may give the veterinarian added information of a disease process.

FIGURE 1. Aggregates of *Lepas anatifera* on the hind flippers of a *Mirounga angustirostris*. Photograph by Lynn Amaya, October 1982.

LITERATURE CITED

Cornwall, I. E. 1955. The barnacles of British Columbia. Brit. Col. Prov. Mus. Handbook 7, 69 p.

Dierauf, L. A. 1983. A survey of live pinnipeds stranded along the northern California coast. Calif. Veterinarian, 6. 22–26.

Evans F. 1958. Growth and maturity of the barnacles *Lepas hilli* and *Lepas anatifera*. Nature, 182: 1245–1246.

Landman, N. H. 1983. Barnacle attachment on live *Nautilus:* implications for *Nautilus* growth rate. Veliger, 26 (2): 124–127.

Pilsbry, H. A. 1907. The barnacles (Cirripedia) contained in the collections of the U. S. National Museum. U.S. Nat. Mus., Bull. 60, 122 p.

Zullo, V. A. 1979. Marine flora and fauna of the northeastern United States. Arthropodia: Cirripedia. NOAA Tech. Rept NMFS Circ. 425, 29 p.

—Jan Roletto, California Marine Mammal Center, Fort Cronkhite, California, 94965 and Robert Van Syoc, California Academy of Sciences, Golden Gate Park, San Francisco, California 94118. *Accepted for publication January 1985.*

BOOK REVIEW

DISTRIBUTION, BIOLOGY, AND MANAGEMENT OF EXOTIC FISHES

Edited by Walter R. Courtenay, Jr., and Jay R. Stauffer, Jr. The Johns Hopkins University Press, Baltimore and London, 1984; 430 p., $40.00.

This excellent book consolidates the papers given at a symposium organized in conjunction with the 1981 American Fisheries Society meeting held in Albuquerque, New Mexico.

The first chapter defines three standardized terms often used in referring to exotic fish issues: (i) *exotic*—any species introduced by man from a foreign land; (ii) *transplanted*—native species moved by man into an ecosystem outside their native range but still within their country of origin; (iii) *nonnative*—any species introduced by man into an ecosystem outside its native range (includes exotic plus transplanted). Although the book's title refers specifically to exotics, the principles discussed in the various chapters apply equally to transplanted fishes, lending support to a proposal by Clark Hubbs that an exotic should be defined as any species introduced to a location outside its natural geographic range. This definition seems to fit better within the context generally used in the fisheries profession, although a consensus does not yet appear to exist.

In the field of fishery science there are few subjects more likely to evoke controversy and emotion than introduced species. Much of the value of this book is derived from the fact that tunnel vision, biological naivete, and political expediency normally preclude more objective rationales in decisions relating to species introductions. The editors have assembled a wealth of information on the subject, both pro and con, to assist biologists and administrators in making often difficult decisions, recognizing that the same importation request that may bring hope and economic gain to an irrigation district anxious to control weeds in a canal system will probably strike terror in the heart of a fishery biologist keenly aware of the probable long term ecological consequences of such an introduction. This is especially true if the biologist's job responsibilities include the preservation of indigenous life forms already seriously impacted by habitat reduction and degradation.

Without exception, the various authors have presented their data and conclusions with clarity and competence. They have pointed out those instances where species introductions (at least in the short term) have been beneficial. Conversely, they have chronicled many of the cases in which introductions have proven to be harmful, and this appears to be the rule. The impact of introduced species on native fishes is emphasized.

The zeal of those who wish to introduce a species to accomplish a specific task is understandable, irrespective of George Santayana's reminder that those who cannot remember the past are condemned to repeat it. This book serves to underline the mistakes of the past, the basis of which should be overwhelmingly clear to any freshman ecology student: whenever a foreign organism is introduced into a naturally balanced ecosystem, something "gives" somewhere. Yet this axiom is all too often ignored or overlooked in the decision making process.

As a field biologist who has spent much of 32 years trying to eradicate or control nonnative fishes, be they largemouth bass or mosquitofish preying on and competing with endangered cyprinodonts, brown trout doing their best to consume the last remaining golden trout in their native habitat, or Sacramento perch threatening to damage a world famous rainbow trout (also a nonnative) fishery, I have often yearned for just such a treatment of the subject as this book provides, if for no other reason than to confirm the observations and rationale that one builds from extensive field experience.

One of my fondest dreams is to be given at some point during my lifetime a magic exotic (or nonnative) species eradicator button which I might press to return the North American fauna to its status prior to the arrival of Europeans. For it seems that there have been few exotics imported, or transplants made, to fulfill needs that could not have been met equally well with native fishes. But until technology develops to a point where we can control fish populations with complete efficiency, our best guide in making introductions must be our past performance in such matters, and Courtenay and Stauffer's book provides just such a guide. In the meantime, those of us who share a spark of idealism can look forward to a new era when advanced technologies might allow us to reverse the current trend and begin the slow process of reverting to a natural fish fauna, at least in certain key areas. Then, based upon our past experiences, we might begin discussing the subject of exotic introductions with a modicum of competence.

It is fitting that the last two chapters should deal with: i) development of an environmental ethic for the introduction of exotic fishes and ii) a suggested protocol for evluating proposed exotic fish introductions in the United States. However, such a protocol, even if strictly adhered to by the regulatory agencies, will do little to prevent the illegal spread of nonnative fishes by ecologically

ignorant or uncaring persons once they are introduced. None of the problems mentioned earlier concerning mosquitofish, largemouth bass, brown trout, or Sacramento perch resulted from authorized introductions. They resulted from someone with a bucket who clandestinely (and disastrously) tried to play fishery biologist.

Relative to the development of an environmental ethic for the introduction of exotic fishes, possibly ethical arguments should carry the greater weight, inasmuch as biological rationales have been largely unsuccessful in controlling the spread of nonnative fishes. Perhaps Aldo Leopold said it best: "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." When nonnative species are put to this test they seldom pass, and *Distribution, Biology, and Management of Exotic Fishes* clearly points this out. The book should be owned and frequently referred to by every biologist, administrator, and public official involved in making decisions relating to the general subject of species introductions.

As an afterthought, I failed to mention one additional value of this hard-covered book. When it was sent to me for review by the Editor-in-Chief of *California Fish and Game,* he enclosed the following note: "Looks like a good book, but maybe the best way to use it is to club people over the head with it when they want to introduce exotics." Everything considered, I emphatically agree. We have a long way to go before we bat even .500 in achieving harmless introductions, and it is vastly easier to plant a species than to unplant it. And if you want a concise summary of the effect of exotics on a native population, simply ask your local Indian chief. *Phil Pister*

FRESHWATER FISHES OF CALIFORNIA

By: Samuel M. McGinnis

University of California Press, Berkeley, London and Los Angeles, 1984; 316 p.,$22.50.

One might reasonably ask why U. C. Press promoted publication of this book so soon after the appearance of Peter Moyle's excellent and relatively recent *Inland Fishes of California.* Very simply, Moyle's book is more in the form of an ichthyology text, whereas *Freshwater Fishes of California* is a layman's field guide to freshwater fish identification, distribution, biology, and human uses.

The organization of the book is sound, and California's native fish fauna is emphasized. The illustrations, both color photographs and black and white drawings, are of exceptionally good quality. In addition, the book is informative concerning California's freshwater habitats, how to photograph a fish, and construct and maintain a freshwater aquarium. It has a useful pictorial key and even adds a section on the joys of fish watching. These are all badly needed components in an inexorable trend to bend an increasingly demanding public toward a less consumptive viewpoint concerning our diminishing fish and wildlife resources.

An interesting appendix provides a checklist of native and introduced fishes, sport fish weight records, a practical guide to fish anatomy, how to clean a fish, and even some excellent suggestions on the preparation and consumption of nongame fishes. The latter sections provide sufficient differentiation to make *Freshwater Fishes of California* a potentially valuable companion volume to *Inland Fishes of California.*

However, a reader with extensive knowledge of California's freshwater fish fauna will gain the uncomfortable feeling that accompanies a good news-bad news story. The good news is that the book makes a reasonable start in its intended direction, but the bad news is that it is replete with a diversity of errors and naivete ranging from the misidentification of species (Plate 22 is an eastern brook charr and not a brown trout) to the description of a technique described as "tickling," in which the reader is instructed to surreptitiously approach a "Brookie," tickle it on the belly, and toss it out on the bank. While this procedure no doubt works, it is also illegal, and the reader should be warned. Otherwise, the resulting fine would probably exceed the $22.50 outlay for the book.

One might expect errors in the first edition of any book of such a broad scope. However, *Freshwater Fishes of California* contains far more than its share, and we are at a loss to explain why U.C. Press, normally cautious in such matters, did not utilize a more competent peer review procedure. This is especially true in view of the fact that the author was writing in a subject area outside of his specialty (herpetology). Vertebrate natural history is too vast afield to allow one the luxury of venturing very far outside of his home territory.

However, *Freshwater Fishes of California* can be corrected in a well reviewed and carefully edited second edition. This will bring it past its current uncertain state and allow it to approach its obvious potential. *Phil Pister and Donald E. Stevens*

INSTRUCTIONS TO AUTHORS

EDITORIAL POLICY

California Fish and Game is a technical, professional, and educational journal devoted to the conservation and understanding of fish and wildlife. Original manuscripts submitted for consideration should deal with the California flora and fauna or provide information of direct interest and benefit to California researchers. Authors may submit an original plus two copies, each, of manuscript, tables, and figures at any time.

MANUSCRIPTS: Authors should refer to the *CBE Style Manual* (Fifth Edition) and a recent issue of *California Fish and Game* for general guidance in preparing their manuscripts. Some major points are given below.

1. *Typing*—All material submitted, including headings, footnotes, and literature cited must be typewritten doublespaced, on white paper. Papers shorter than 10 typewritten pages, including tables, should follow the format for notes.

2. *Citations*—All citations should follow the name-and-year system. The "library style" will be followed in listing references.

3. *Abstracts*—Every article must be introduced by a concise abstract. Indent the abstract at each margin to identify it. Abstracts, on separate sheets of paper, should accompany "Notes".

4. *Abbreviations and numerals*—Use approved abbreviations as listed in the *CBE Style Manual*. In all other cases spell out the entire word.

TABLES: Each table should be typewritten with the heading left margin justified. Tables should be numbered consecutively beginning with "1" and placed together in the manuscript following the Literature Cited section. Do not double space tables. See a recent issue of *California Fish and Game* for format.

FIGURES: Consider proportions of figures in relation to the page size of *California Fish and Game*. The usable printed page is 117 by 191 mm. This must be considered in planning a full page figure, for the figure <u>with its caption</u> cannot exceed these limits. Photographs should be submitted on glossy paper with strong contrasts. All figures should be identified with the author's name in the upper left corner and the figure numbers in the upper right corner. Markings on figures should be made with a blue china marking pencil. Figure captions must be typed on a separate sheet headed by the title of the paper and the authors name.

PROOFS: Galley proofs will be sent to authors approximately 60 days before publication. The author has the ultimate responsibility for the content of the paper, and is expected to check the galley proof very carefully.

PAGE CHARGES AND REPRINTS: All authors will be charged $35 per page for publication and will be billed before publication of manuscripts. Reprints may be ordered through the editor at the time the proof is submitted. Authors will receive a reprint charge schedule along with the galley proof.

POSTMASTER: RETURN POSTAGE GUARANTEED

Editor, CALIFORNIA FISH AND GAME
CALIFORNIA DEPARTMENT OF FISH AND GAME
1416 NINTH ST., SACRAMENTO, CA 95814

BULK RATE
U.S. POSTAGE
PAID
Sacramento, Calif.
Permit No. 949